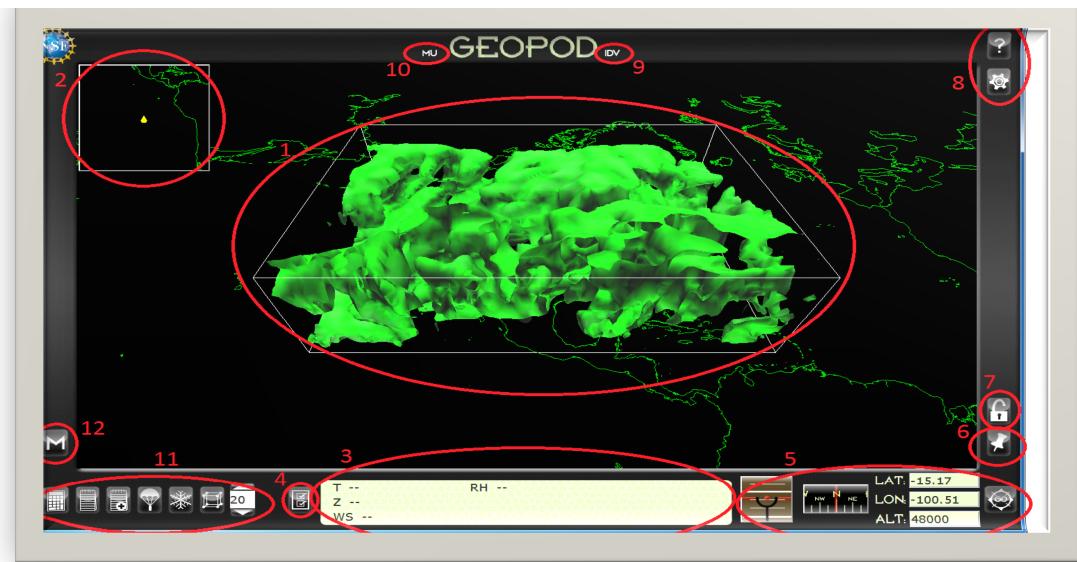


# Millersville University

## Department of Earth Sciences

**GEOPOD (GEOscience Probe of Discovery): A Three-Year  
Project Funded by the National Science Foundation  
(2009-2012)**



## GEOPOD Final Evaluation Report

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Submitted  
by

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## I. INTRODUCTION

### Project Background and Purpose

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

The purpose of the **GEOPOD** project was to develop and implement an interactive instructional software program, the **GEOpod**<sup>1</sup>, which would provide instructors and students in the field of Meteorology with an intuitive and graphical interface in a 3-D gaming environment and a GUI plug-in that would offer an immersion world experience within the IDV framework. The goals of the project were to provide users with a software program that would allow 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 leveraged 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 rendering a 3-D data environment which serves as an exploration platform for the **GEOpod**. Key features of the **GEOpod** include:

- Easy to use interface, accessible to novices and experts alike;
- Customizable display panel with drag-and-drop capability for 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;

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<sup>1</sup> **GEOPOD** refers to the overall project and **GEOpod** refers to the interface.

- 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;
- A particle imager which displays hydrometeor type and ice crystal habits based on inputs of temperature and relative humidity;
- A virtual dropsonde which provides vertical profiles over the closest grid point and can save multiple soundings;
- A grid-point displayer which allows the user to view the underlying model grid framework;
- Point-of-interest annotation: Using a noted-locations system the user is able to annotate (and later view, edit, or save) parameter values at points of interest;
- Flight recorder for evaluation and assessment: Ability to “fly” directly and with variable speed to a point location within the grid or retrace the entire traverse, or save and send the full exercise to the instructor for replication and evaluation;
- Auto-build and replay of IDV bundles;
- Web-based “mission builder” for user or instructor with defined missions that serve as guided exercises for the user; and
- Learning objectives and assessments.

The GEOPOD project developers believed that, applied prudently and intelligently, technology holds great promise as a means to improve education and that it can be implemented without unrealistic increases in spending. Presnyk (2003) has framed the significance of computer technology and simulations in terms of the fundamental characteristics of effective learning: Active engagement, participation in groups, frequent interaction and feedback, connections to real-world contexts, and learning by doing.

There is little doubt in academia or among the public at large about the importance of computer technology as a tool for learning, especially at the undergraduate and graduate level in the 21<sup>st</sup> century (How People Learn, 2000). Across many disciplines, but notably in the geosciences, computer technology as a tool for access to data and Web-based resources, and computational problem solving is the life-blood of the curriculum. Today, students in higher education have access to real-time and legacy datasets, sophisticated visualization applications,

high-bandwidth networks, and high-speed computers. These students, the so-called “Millennials” or the Net Generation, have grown up with computers and are technologically savvy (Oblinger, 2004). They are accustomed to operating in a digital environment, communicating with cell phones, text messaging, and email—have computers at home and have access to multiple types of mobile devices equipped with wi-fi. By contrast, and despite huge investments in communication and computer hardware and software made by universities and schools, most formal teaching and learning still uses methods that would be familiar to a 19<sup>th</sup> century student: reading texts, listening to lectures, and participating in highly scripted laboratory exercises (Kelly, 2005).

In recent years, the use of electronic games for experiential learning has generated considerable interest. Advocates suggest that gaming could increase student enthusiasm for educational materials, which could in turn increase time on task and lead ultimately to improved motivation and student performance (The Learning Federation Project, 2003). Educators have already begun introducing games into instruction (e.g. “Discover Babylon<sup>©</sup>, Civilization II<sup>TM</sup>, SimCity<sup>TM</sup>, and Immune Attack<sup>TM</sup>), and will continue to benefit from commercial inroads into gaming in education so long as such applications are based on a sound understanding of which features of these systems are important for learning and why (Kelly, 2005).

It was the promise of this kind of interactive technology and the potential benefits for instructors and students in the field of Meteorology that provided the impetus for this **GEOPOD** project and the design of the **GEOpod**. The challenge in the **GEOpod** design was 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 in a 3-D environment (e.g., surface and upper air observations, satellite and weather radar imagery) and the use of numerical model output based on actual physics such that it exhibits technical accuracy, fidelity, and scientific soundness. It was the hope of the designers of GEOpod that this instructional technology would appeal to “net-geners” who are adept at computerized systems and gaming, and motivate them to explore the data volume in a way that would ultimately lead them to a greater understanding of meteorological concepts.

The three goals of the **GEOPOD** project were: (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 excites and motivates 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. GEOpod project documents that further explain these goals are available on the project website: <http://csheadnode.cs.millersville.edu/~geopod/index.html>.

## **Scope and Duration of the Project**

The **GEOPOD** project consisted of three phases over a three year period (2009-2012):

**Phase I: Design and Development of the GEOpod** (September 1, 2009- June 30, 2010) consisted 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 II: Testing and Rollout of the GEOpod** (July 1, 2010-June 30, 2011) included continued development and rollout of the GEOpod technology, design and implementation of the GEOpod Usability Study, and testing of comparison groups using the GEOPOD assessment instrument.

**Phase III: Implementation and Assessment** (July 1, 2011-June 30, 2012) consisted of the continued refinement of the GEOpod technology, GEOpod mission building, training of students on the GEOpod, implementation of the GEOpod in selected classes, and assessment of learning outcomes for students who were taught using the GEOpod. This final evaluation report presents the highlights of a formative evaluation of the first two phases of the project and the summative results for Phase III (2011-2012). Full evaluation reports on Phases I and II of the project can be found on the project website (<http://csheadnode.cs.millersville.edu/~geopod/index.html>).

## II. EVALUATION DESIGN AND METHODOLOGY

### Evaluation Goals and Objectives

The 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** technology and missions<sup>2</sup>, and the extent to which students realize learning gains as a result of using the **GEOpod** technology and missions in their courses.

Formative evaluation results for Phases I and II, which include the design, development and testing of the **GEOpod**, offered 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 Phases I and II were the following:

- *To what extent was the project carried out in Phases I and II as originally designed? What course corrections/changes were made and to what end?*
- *What progress has been made in Phases I and II in the development of the GEOpod platform?*
- *What tests of functionality, technical soundness, and user interactivity were conducted on the GEOpod and with what results?*
- *What student assessments were developed and tested during Phases I and II and with what results?*
- *To what degree were faculty trained in the use of the GEOpod platform in their courses?*
- *To what degree are the project collaborators and the GEOpod technology ready for implementation in Phase III, fall term 2011?*

The summative evaluation, which was conducted during Phase III, consisted of an examination of implementation and assessment activities. This summative evaluation was designed to provide evidence of (1) increased student learning outcomes as a result of using the

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<sup>2</sup> Missions are guided exercises for use with the **GEOpod**.

GEOpod technology in the classroom, (2) the extent to which instructors and students value and use this technology in instruction and learning, (3) the extent to which this kind of technology can be sustained in instruction at Millersville University, and adopted at other universities or institutional settings nationwide. The specific research questions guiding the Phase III evaluation included:

- *To what extent were the **GEOpod** missions used and valued by instructors as a teaching tool at the university level?*
- *Did instructors require additional technical assistance beyond the initial training with the **GEOpod**? If so, what was the nature of that training and how was it delivered?*
- *To what extent were students able to successfully complete a series of **GEOpod** missions or modules?*
- *To what extent were the **GEOpod** modules used and valued by students as a learning tool?*
- *To what extent did students experience content knowledge learning gains as a result of using the **GEOpod** in instruction? Where these gains different for different subgroups of students (e.g. freshman, male/female, science majors, etc.)*
- *To what extent can this kind of technology be sustained as a learning tool at Millersville University?*
- *To what extent does the **GEOpod** technology have wide appeal and potential for adaptation at other colleges, universities, and educational settings around the country?*

## **Data Collection Activities and Instruments**

The external evaluator, in collaboration with the Millersville GEOPOD project staff, designed the following instruments and protocols for data collection during the three phases of the project.

- **Document Review:** A systematic content review of all meeting minutes, timelines, and other project documents to determine decisions, the direction of the project, and activities completed during all phases of the project.
- **Usability Study.** A study to test the soundness of the GEOpod technology platform and the human interactivity component. The goals of usability test included: (1) establishing a baseline of user performance, (2) establishing and validating user performance measures, and (3) identifying potential design

concerns to be addressed in order to improve the efficiency, productivity, and end-user satisfaction.

- **Instructor Log.** Web-based instrument for instructors to record their weekly use of the GEOpod in instruction, the curriculum materials used, student reactions to the technology, and any challenges or benefits they experienced in using the technology. This weekly log also acted as a monitoring tool, allowing project staff to track any challenges instructors were having in using the technology in order to provide additional training and guidance.
- **Student Learning Outcomes Assessment.** In order to determine the extent to which students demonstrated gains in content knowledge as a result of instruction using the ***GEOpod***, a pre/posttest measure of student learning developed by the project team and the external evaluator was administered to Comparison groups<sup>3</sup> (students who had no exposure to the GEOpod) and Treatment groups (students who were exposed to the GEOpod in their courses).
- **Survey of Student Research Assistants.** A survey delivered to the undergraduate researchers who were charged with developing the GEOpod.
- **Web-based Student Survey.** In order to corroborate information gleaned from the instructor logs, students were asked to respond (anonymously) to a survey that requested their opinions of the impact GEOpod on their learning as well as their perceptions of any improvements in classroom atmosphere and instructional quality as a result of using the GEOpod in their courses.
- **GEOPOD Project Team Interview Protocol.** An interview conducted at the end of Phase III with the project staff to determine their perspectives on the major successes or accomplishments of the project, factors that facilitated or impeded progress, and lessons learned.

## Organization of the Report

This final evaluation report represents the results of the GEOPOD project activities from all three phases of the project. Section III presents highlights of the formative evaluation of the

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<sup>3</sup> Comparison groups are 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.

project. Section IV describes the key implementation activities of the project during Phase III, including continued changes to the technology of the GEOpod, training activities, development of the missions, and use of the missions in instruction. Section V presents the summative evaluation of Phase III, including the results from the assessment of student learning and student and instructor opinions regarding the value and usefulness of the GEOpod. Section VI provides lessons learned from the perspective of the project staff, and Section VII details the conclusions and recommendations from the evaluator's perspective.

### **SECTION III: HIGHLIGHTS OF THE FORMATIVE EVALUATION, PHASES I AND II OF THE GEOPOD PROJECT (September 2009-June, 2011)**

What follows in this section is a brief summary and highlights of the activities and outcomes of Phases I and II of the GEOPOD project which occurred from September 1, 2009 to June 30, 2011. The formative evaluation of first two phases of the GEOPOD project focused on an examination of the following activities: Development and testing of the GEOpod technology; development and testing of the student assessment instrument designed to measure student learning outcomes following use of the GEOpod in instruction; and efforts to disseminate preliminary information on the GEOpod to the professional meteorological community. The evaluation results, conclusions and recommendations from these two beginning phases of the project are detailed in two evaluation reports (Mackin, 2010 and Mackin, 2011) which are available in full on the project website (<http://csheadnode.cs.millersville.edu/~geopod/index.html>).

#### **Phase I: Design and Development of the GEOpod Technology and Instructional Assessment**

During Phase I (September 1, 2009-June 30, 2010), Dr. Zoppetti and his team of Millersville undergraduate student researchers were engaged in the development of the GEOpod technology. Over the course of the project the following Millersville students worked on the GEOpod design, development, and implementation:

- Ky P. Waegel, Computer Science Department, CSCI
- Michael R. Root, Computer Science Department, CSCI
- Lindsey M. Young, Computer Science Department, CSCI
- Neil T. Obetz, Computer Science Department, CSCI
- Pavlo M. Hrizhynku, Computer Science Department, CSCI
- Lindsay R. Blank, Earth Science and Computer Science Departments (ESCI major, CSCI minor), Testing of the GEOpod
- Timothy W. Juliano, Earth Science Department, Testing of the GEOpod

Drs. Richard Clark and Sepi Yalda were engaged in developing the GEOpod missions for instructional use and in the development and implementation of an appropriate assessment instrument to determine the extent to which students realize enhanced learning outcomes as a result of instruction using the GEOpod in their courses. In addition to developing the assessment instrument, the GEOpod team tested this assessment tool with a group of Millersville University (MU) students enrolled in Meteorology courses to determine test reliability and validity. These development efforts and assessment testing procedures are further explained below.

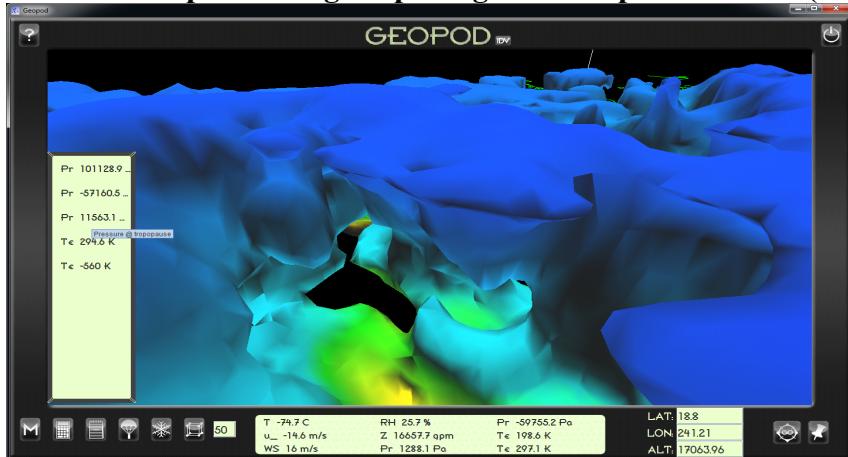
### **Development of the GEOpod Technology**

During the fall, spring, and summer terms of 2009 and 2010, the GEOpod technology was developed by Dr. Gary Zoppetti with the assistance of three students in the Department of Computer Science at MU. Drs. Richard Clark and Sepi Yalda were also involved from the beginning as the system was being developed, guiding the establishment of parameters, key features, and applications. This kind of interaction and collaboration between the Computer Science Department and the Earth Sciences Department was key to guiding the design of the product, ensuring that the GEOpod not only met specifications, but also addressed the needs and capabilities of the potential users.

The student researchers devoted over 1,000 hours to the development of the GEOpod. During this time they learned about the GEOpod project, meteorological terms and concepts, and the required technologies they would be working with—specifically Java 3D and IDV functionality and software architecture. During spring of 2010, the technology team began to implement the switch from a fixed to a movable camera that allowed them to sample the atmosphere at its current location and put into operation a minimal heads-up display.

During the summer of 2010 an additional student from the Computer Science department joined the team to further refine the technology. Over the summer months, the four students built and refined the GEOpod interface, implemented the sensor, dropsonde, and particle image devices and developed the mission subsystem and the flight recorder. (See Exhibit 1 for a graphic of the GEOpod technology at this early stage). Because of the team's diligent efforts, the GEOpod technology was ready for testing with the student population in the spring and fall terms of 2011.

**Exhibit 1: A photo image depicting the GEOpod interface (early development in 2010).**



**Note:** The primary parameter area pictured in the bottom center of the photo displays atmosphere parameters such as temperature and wind speed. Buttons on the lower left, lower right, and upper left allow the user to activate devices, view a mission, and obtain help. An overflow display on the left shows parameters beyond the 9 primary parameters. Seen through the HUD is an isosurface of relative humidity (a surface where the relative humidity is constant). The advanced user can select more parameters than the nine (9) that the primary display area shows. The overflow display (on the left) will become active when the user accesses it. All parameters have a tooltip that shows their full name (rather than a common abbreviation) when the user hovers over it.

### **Design and Testing of the GEOPOD Assessment Instrument**

In January 2010, Drs. Clark and Yalda, in collaboration with the project evaluator, developed a pre/posttest measure for the GEOPOD project. The assessment consisted of 19 items and was designed to be given as a pre and post-test measure to both the Treatment and Comparison groups.<sup>4</sup> This assessment instrument was critical to the project in that it would allow the team to determine, in part, the efficacy of the GEOpod technology used in instruction and the extent to which students realized learning gains as a result of using the GEOpod technology.

Four items on the assessment addressed student demographics (e.g. course enrolled, college level, major, and gender) and two background items addressed students' experience with

<sup>4</sup> 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.

3-D gaming and computerized navigational systems and students' experience with research methodologies and strategies in the sciences. Thirteen multiple-choice questions addressed content that is generally taught in undergraduate meteorological courses and related to the missions addressed in the GEOPOD project. Target concepts included: Basic kinematics of fluids, relationship between thermodynamic and kinematic fluids, cloud microphysics, and the nature of ageostrophic wind.

In order to determine test validity and any issues with the particular test questions, the GEOPOD assessment was reviewed by selected faculty for face validity and piloted with a group of eighty-nine students who were enrolled in the following four courses at Millersville in the spring term of 2010:

- Physical Meteorology,
- Atmospheric Dynamics II,
- Climate Dynamics, and
- Meso/Storm Scale Meteorology

Results of the assessment which was administered to students through the university's Blackboard<sup>5</sup> learning platform suggested that the GEOPOD assessment, with minor adjustments to several items found to have an unusually high correct response rate, appeared to be a good measure of pretest knowledge for a range of students and would serve as a reliable pre and posttest measure of student learning for the project's Treatment and Comparison groups. (For a full discussion of these assessment results, see Mackin, 2010.)

## **Phase II: Testing and Rollout of the GEOpod Technology**

During Phase II of the project (July 1, 2010-June 30, 2011), the GEOPOD project staff engaged in a number of activities to further develop and test the GEOpod technology, including a formal Usability Study to ensure that the technology would be ready for classroom implementation in Phase III of the project. Also, 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 for the study. Dissemination of information about the GEOpod was also

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<sup>5</sup> Blackboard was used in 2010, but later replaced with Desire To Learn (D2L) in subsequent years.

carried out during this phase, including the development of a project website (<http://csheadnode.cs.millersville.edu~geopod/index.html>). Outcomes from each of these activities are briefly discussed below. The full project report for Phase II can be found on the project's website.

### **Further Refinement of the GEOpod Technology and the Usability Study**

During the summer and fall terms of 2010 and the spring term of 2011, the GEOpod technology continued to be developed by the undergraduate students under the direction Dr. Gary Zoppetti and supported by Drs. Clark and Yalda. The students worked approximately 1,200 hours in developing the GEOpod technology during Phase II of the project. In addition to these activities, the GEOPOD project team engaged in a Usability Study of the GEOpod software system with Dr. Blaise Liffick of Millersville's Computer Science Department to determine the technological soundness of the GEOpod and any navigational and instructional issues that might occur for students and instructors who would use the system (Liffick, B. W, 2011).

Subjects for the Usability Study were 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 received a small stipend for their participation. Testing took place in the Adaptive Computing Lab of the Department of Computer Science, Millersville University and the fifteen students were tested in two-hour time slots. Students in Dr. Liffick's Computer Science class were trained and subsequently engaged as testers in the process. This study 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 the Usability Study validated the work of the GEOpod research and development team and provided the guidance they needed to revise the GEOpod system and ultimately enhance the GEOpod product.

Dr. Liffick's recommendations also offered valuable feedback to the GEOPOD project team beyond design and interface issues. His recommendations included advice to plan for

explicit training on the GEOpod system before students and teachers were asked to use it in instructional settings. Dr. Liffick suggested that adequate training on the system would help minimize mistakes caused by inexperience and that the phrasing of task statements should be reviewed for clarity so that they would be adequately understood by users of the system as misunderstanding task statements could lead to unnecessary errors in execution. Dr. Liffick concluded 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 research and development team and corrections were made in the spring term of 2011; refinements to the GEOpod system, based on this study, continued in summer of 2011.

Due to the technology team’s 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 was ready for implementation in selected Meteorology courses in the fall semester of 2011. After testing and minor adjustments, the assessment system was also ready for use.

### **Testing of All Comparison Groups Using the GEOpod Assessment**

Given that the GEOpod system was not fully ready for use in classrooms in the fall semester of 2010 and the GEOpod “missions<sup>6</sup>” had not been developed, 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 for this study. 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 classes participated in the pre/posttest administration in fall, 2010.

#### **Comparison Group Classes, Fall Term, 2010**

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

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<sup>6</sup> Missions are exercises or instructional modules used to guide instruction on the GEOpod.

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 resulted in a solid and reliable set of student outcome data from which to judge the reliability and validity of the assessment instrument. Test administration went flawlessly using MU's new online system, D2L (Desire to Learn), and students were cooperative in taking the assessment. These standardized procedures would again be used in Phase III as Treatment group students enrolled in similar Meteorology courses would be given the same assessment after exposure to instruction using the GEOpod. 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. This assessment instrument is critical to 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. (For a full report on the Comparison group testing, see Mackin, 2011).

### **Dissemination of Information about the GEOpod**

**Development of a Project Website and Presentations.** During Phase II, the project team developed a project website (<http://csheadnode.cs.millersville.edu~geopod/index.html>) and presented information on the GEOpod at professional meetings. The project website was helpful as it allowed the project team to share project successes with the wider science community. The following types of items are included on the website: project documents, documentation about the GEOpod technology, the User's Guide, instructional "missions," the Usability Study, presentations, and links to other related sites.

In late January, 2011 two of the student GEOpod developers, seniors Ky Waegel and Michael Root, demonstrated the GEOpod technology at the 91<sup>st</sup> annual meeting of the American Meteorological Society (AMS) in Seattle, Washington (see video of the presentation on the project website) The title of their presentation was *GEOpod: An Interactive Module for Navigating and Probing Geophysical Data*. 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. 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 student presentation at AMS was very well received as suggested by the enthusiasm expressed by the audience. The audience also posed a series of questions which were very helpful to the project team in understanding any issues other instructors or professionals in the field might have with the GEOpod. These questions and answers can be found in the Phase II report (Mackin 2011).

### **Feedback from Student Researchers Regarding Their Involvement in the GEOPOD Project**

One of the other outcomes of the project not formally factored into the evaluation plan was the impact that GEOPOD research work had on the student researchers themselves. This is a project outcome that goes beyond the development of the GEOpod system for classroom use as it profoundly influences the lives and learning of the student designers themselves. In a survey asking the student developers of the GEOpod their opinions about the project and their own involvement, the students expressed that their work on the project resulted in many lessons learned; lessons that influenced how they thought about their chosen field of computer science and the direction of their own future graduate study and/or careers.

They reported that intensive and sustained work on this project provided them with a valuable window into the working world of research and development in the computer science field. This was an opportunity that is 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 the confidence that they could tackle difficult research tasks in potential jobs or in graduate school.

Under the careful mentoring of Dr. Zoppetti these students gained invaluable and rich real world research and development experience that was not available in their classroom work, experiences that will influence their postgraduate study and careers for years to come. (For a more detailed account of the responses from the student research and development team, see Mackin, 2011).

## **Summary**

Activities from Phases I and II of the project set the stage for classroom implementation of the GEOpod technology in Phase III. Dr. Zoppetti and his team with the support of Drs. Clark and Yalda successfully developed the technology for the GEOpod and through the Usability Study Dr. Liffick provided critical feedback on the functionality of the system. An outcomes assessment instrument was validated and tested with students in conditions that would later be duplicated with a Treatment group of students exposed to the GEOpod in Phase III of the project. What the project team essentially did in Phases I and II was to conduct a “beta test” or a “test of concept,” determining the sophistication, functionality, and usefulness of the GEOpod technology with a college population of students. The stage was set in Phases I and II for the successful implementation of the GEOpod in the classrooms in Phase III.

## **SECTION IV: KEY IMPLEMENTATION ACTIVITIES OF PHASE III (JULY, 2011-JUNE, 2012)**

The goals and objectives of Phase III of the GEOPOD project during the fall term of 2011 and the spring term of 2012 were to: (1) Train students in the use of the GEOpod technology; (2) further refine the GEOpod technology and resolve any remaining bugs in the system; (3) develop the instructional “missions” to be used with the GEOpod in instruction; (4) use the GEOpod in instruction; and (5) examine student learning outcomes following the use of the GEOpod in instruction. What follows is a description of the activities of this phase of the project.

### **Training Students to Use the GEOpod**

Early in the fall term of 2011 and again in the spring term of 2012, one of the student research and development team members developed and delivered training sessions on the GEOpod for students who were expected to be exposed to the technology in their courses during the term. These trainings followed Dr. Liffick’s suggestion from the Usability Study and

discussions among the project staff that students would need training on the system to be certain that they understood the navigational functions and capacity of the system and ensure maximum use and engagement with the system. While many glitches happen at the launch of any new product in education, it's important that students stick to prescribed and consistent protocols in the use of new technology to achieve optimal results, maximize learning, and ensure that the technology enhances and does not interfere with student learning. The following classes were engaged in the training early in the school term:

### **Fall Term, 2011**

- ESCI 441 Synoptic Meteorology
- ESCI 341 Atmospheric Thermodynamics
- ESCI 241 Meteorology (lecture and lab) [three separate sections]

### **Spring Term, 2012**

- ESCI 444 Meso/Storm Scale Meteorology

The trainer reported back to the GEOPOD project team and the evaluator on the results of the training and her suggestions for future trainings on the GEOpod system. Her feedback and suggestions are detailed in brief below:

- Some students tried to use IDV features that GEOpod was not compatible with and thus experienced serious errors, such as inability to rotate, choppy or distorted images, and one or more large stationary yellow cones present inside the data volume. [These problems were encountered in fall, 2011 and rectified in spring, 2012.]
- Some students were unsure about the applicability to GEOpod to the content of their courses. [This was due in part to the fact that some professors were absent during some of the training sessions in fall, 2011, thus unable to draw the connection to content students would be encountering. This situation was rectified in spring, 2012. The instructors were present at the training and made statements connecting the GEOpod missions to content the students would be studying.]
- Some students “caught on” to the system faster than others. Those who were unfamiliar with this kind of sophisticated technology needed some kind of electronic document with clear step by step instructions and screenshots to aid

them in trouble shooting or working through steps at their own pace. [Subsequent to these trainings, a GEOpod User's Guide was developed to aid instructors and students in engaging with the system. This User's Guide is available on the project website.]

- Some students in upper level classes appeared more interested in the GEOpod technology than lower level classes. The upperclassmen asked questions such as *How many parameters can be displayed?* or *How do you launch a dropsonde?* Lower levels students and those unfamiliar with 3-D gaming were more engaged with just learning the system.
- Some specific issues arose around loading the technology which hampered some students from engaging fully:
  - Problems with various elements of the “Field Selector” tab being set up properly before starting the GEOpod.
  - Loading the GEOpod without the isosurface.
  - Not remembering to expand the “3D Surface” link, or not selecting “isosurface” when the link was expanded, or not realizing the need to use “CTRL” when clicking one of the options.
  - Some students had difficulty locating some functionality buttons, not realizing that they were off screen.

On a more positive note, the trainer reported that almost all of the students were able to start GEOpod on their own and appeared to be using its features without a problem. The training in spring of 2012 went much better as more time was spent (almost 2 hours) in the training and the professor was present to answer the questions directed more toward content. The trainer's experience points out two significant points about training on the GEOpod. First, regardless of the level of students or experience with 3-D gaming or computerized data systems, it's important that they are trained on the unique functions of the GEOpod and have the time to “play” and become comfortable with the system in the presence of someone familiar with the technology who can answer their questions. It's also important that professors are present at the training so that they can reinforce meteorological concepts that are being displayed on the GEOpod system and connect this information to content the students will be learning in the course. Both of these conditions will ensure maximum results in using the GEOpod in instruction.

## **Further Refinement of GEOpod Technology**

Throughout fall of 2011 and spring of 2012, the GEOpod technology development team continued to make corrections to the system to ensure flawless connectivity and use. Below is a list of some of the bugs that were fixed by the technology team:

- Isosurface lock limited the GEOpod's movement to the center of the surface.
- Keyboard would sometimes lock up.
- IDV button did not iconify windows correctly.
- Flight log did not persist across sessions.
- Particle imager would sometimes display an incorrect image.
- Parameter loading panel disappeared on a keypress.

In addition to the fixes, they added new features to the system, such as:

- GEOpod window was resized to fit on the ESCI screens (without having to move the window).
- Added a key to move the GEOpod to the top center of the data volume.
- Refined the parameter chooser to shuttle parameters from available to selected and vice versa.
- Added an isosurface display panel for adding and removing surfaces (a detail that needed further testing in summer, 2012).
- Working on a distance calculator.

## **Development of the GEOPOD Missions**

During Phase III of the project, Dr. Sepi Yalda developed the GEOpod “missions” or learning modules that serve as guided exercises for the GEOpod user. Each mission includes a set of learning objectives and questions for assessment supported by a detailed assessment rubric that can be utilized by both instructor and student. An accompanying “Mission Builder” was also developed that gives the GEOpod user the ability to create customized missions; a student using the GEOpod would click on a mission icon to access preloaded exercises and use gridded data sets. The GEOpod missions developed to date are listed in Exhibit 2 and a full description

of these missions and accompanying lessons are available in on the project website.

<http://csheadnode.cs.millersville.edu/~geopod/index.html>.

### Exhibit 2: The GEOpod Missions

Mission Title	Mission Description
<b>Fronts</b>	Exploring the 3-D structure and location of a cold front. Exploring the locations of fronts.
<b>Jet Stream</b>	Exploring the 3-D structure of the jet stream. Navigating through the jet stream to explore the horizontal and vertical structure and the connection to the formation of storm systems.
<b>Constant Pressure Surface</b>	Exploring 3-D structure of constant pressure surfaces and the connection to geopotential height variability.
<b>Thermodynamic Structure and Stability</b>	Examining the thermodynamic structure of the atmosphere and stability parameters.
<b>Upper Level Winds and Stability</b>	Exploring the upper-level wind structure and relationship to the stability structure of the atmosphere.
<b>Vorticity and Mesoscale Features</b>	Exploring areas of vorticity and examining the relationship to mesoscale feature development.

The missions that have been developed provide an invaluable tool for professors interested in using the GEOpod to maximum student engagement and learning effects in the classroom. For instance, the mission on *Exploring the Jet Stream* contains sections such as background, graphics, and directions in using the GEOpod for exploration, mathematical computations, real-world simulations and guiding questions. (See Appendix A for an excerpt of the mission, Exploring the Jet Stream.)

### Instruction in Classrooms Using the GEOpod

The GEOpod technology and GEOpod mission on the *Jet Stream* was used in the lab section of the ESCI Meteorology course in the fall term of 2011. In the spring of 2012, the GEOpod missions, *Jet Stream*, *Thermodynamic Structure and Stability*, and *Vorticity* were used in instruction with senior level students in ESCI 444, Meso/Storm Scale Meteorology. Due to the fact that some of the missions were not complete until the end of the semester and that the instructors and project staff were involved in other university-related, time consuming tasks and responsibilities during both terms, the introduction of these GEOpod missions was restricted, in both cases, to the last week of the term; a condition which severely limited each student's ability to truly profit from instruction with the GEOpod. These limitations will be further discussed in Section VI: Lessons Learned.

This limited exposure did, however, provide an opportunity for the project staff to see how the GEOpod would function in the classroom, how the GEOpod missions would fit into the ongoing curriculum, and also gauge how students would react to the technology. In order to answer some questions about the use of GEOpod in the classroom, the course instructors were asked to fill out an Instructor Log (see Appendix B) detailing the missions used, their instructional approach, student reactions, additional materials used and the benefits and challenges of using the GEOpod in instruction. The responses from two of these instructor logs submitted in 2011 and 2012 are summarized below.

Instructor logs were submitted for each of the classes that were taught using the GEOpod in the fall and spring terms: ESCI 241 Meteorology Lab and ESCI 444 Mesoscale Meteorology. The jet stream mission was used in instruction in both terms; two additional missions were introduced in the spring term-Thermodynamic Structure and Stability, and Vorticity. The missions were used primarily to support a lab session or a lecture on the same content. In both classes, the instructor made use of comparative representations of the same phenomena in addition to GEOpod, such as the planview Numerical Weather Prediction (NWP) images and satellite images and traditional views of the jet stream as presented on [rap.ucar.edu/weather](http://rap.ucar.edu/weather).

On the log, instructors are asked to comment on the student reactions to the GEOpod and in both cases, the instructor teaching both courses said that the reaction of the students was uniformly positive. He reported that some students expressed that the GEOpod was like a fun video game and that most students were quite engaged and motivated to participate; this was especially true for the students with prior gaming experience.

The instructor reporting felt that the primary benefit of the GEOpod was exposing the students to the new instructional technology. The instructor responded that the primary challenge during these sessions was the failure of some workstations to support GEOpod. Also, during the training period before launching the mission, it was a challenge to hold students' attention. While the instructor did not have an opportunity to test students following use of the GEOpod, his opinion was that it had enhanced student understanding and certainly aided in their engagement with the content. He reported that he would definitely use the GEOpod in instruction in the future.

## **SECTION V: SUMMATIVE EVALUATION OF PHASE III OF THE GEOPOD PROJECT**

In order to determine the efficacy of the GEOPOD approach in instruction in meteorology courses and the extent to which professors and students use and value the GEOpod technology, the evaluator conducted three evaluation activities during Phase III: (1) Analyzed student pre and post test data comparing Treatment and Comparison group scores to determine the extent to which the GEOpod enhanced learning outcomes for undergraduate students; (2) implemented a survey with students who had been exposed, albeit briefly, to the GEOpod in instruction; and (3) interviewed project staff to determine their perspectives on the results of the project, lessons learned, the potential sustainability of the GEOPOD approach at Millersville, and the extent to which this approach has wider appeal for educators in other educational settings.

### **Student Learning Outcomes**

In order to determine the extent to which students demonstrated 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 was administered to all students in both the Treatment and Comparison conditions. (See Section III of this report for a description of the content of the assessment). During fall term of 2010 and the spring term of 2012, the GEOPOD pre/posttest test was administered to the Comparison and Treatment groups through the college's new online learning platform, Desire to Learn (D2L). While a total of 64 students were tested in the Comparison group in fall of 2010 across four classes, only scores from the 25 seniors in the Comparison group were used in this final analysis. The reason for this change is that only 21 seniors were enrolled in ESCI 444 Mesoscale Meteorology in the spring term of 2012, the only class that received instruction using the GEOpod (the Treatment Group). For comparative purposes, only scores from seniors in both conditions were used.

#### **Comparison Group Classes, Fall Term 2010**

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

#### **Treatment Group Classes, Spring Term 2012**

- ESCI 444 Mesoscale Meteorology

All students in both conditions received course credit for completing both the pre and posttest and students were allowed to take the pretest unmonitored outside of class time. The assessments however were timed and students were timed out if they did not complete a test within a 20 minute window. All scores were calculated on students' available matched<sup>7</sup> scores on the GEOPOD pre and posttest. Only scores for students who had matched scores on the pre and posttest were used for this analysis. The total number of senior level Comparison group students who had both pre and posttest scores available for scoring and analysis was 25; the number of Treatment group students was 21. The sample size for both conditions was not large enough to conduct any robust statistical analysis; therefore the results are presented only as descriptive or summary data. Also, it is important to note that the students in the Treatment condition were introduced to the GEOpod only during the last week of the spring term. Thus, any conclusions about the impact of learning cannot be drawn after such a limited exposure to the GEOpod in the classroom. Results examining the differences between the Comparison and the Treatment groups are thus presented solely for the purpose of discussion. These comparative results for the Comparison and the Treatment groups are discussed below and illustrated in Exhibit 3.

All of the senior level students who took the pre and post test in both conditions were majoring in Meteorology. 47% (8) of the students in the Comparison group were females; 33% (5) were females in the Treatment group. (See Exhibit 3). The Comparison group and the Treatment group scored similarly on the pretest, 31% and 33% respectively. (See Exhibit 4). The Comparison group exhibited an almost 2 point gain overall on the posttest, a gain that would at the least be expected after a full course of instruction during a term. The Treatment group, *which received only a limited amount of instruction at the very end of the term using the GEOpod*, actually lost points at the posttest.

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<sup>7</sup> Students were matched by name, gender, and unique email username.

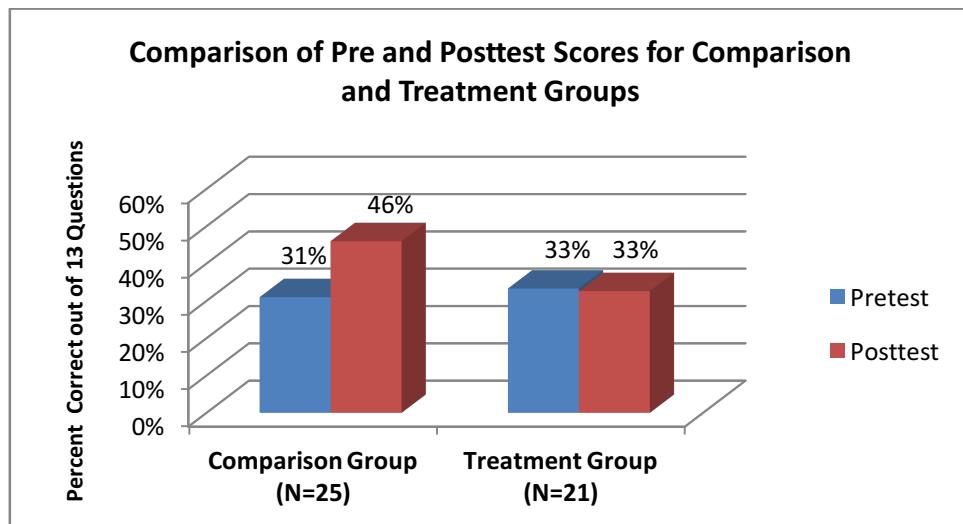
**Exhibit 3. Comparison Scores for Comparison and Treatment Groups on Pre and Posttest and by Gender Subgroups**

Student Groups and Subgroups	Number of Students	Average No. Correct		Pretest		Posttest		Average Gain Score from Pre to Posttest
		Pre	Post	Min	Max	Min	Max	
<b>Comparison</b>	25	4.08	6.0	1	8	3	10	+1.92
Male	17	4.65	6.0	1	8	3	10	+1.35
Female	8	2.85	5.0	1	6	3	6	+2.15
<b>Treatment</b>	21	4.33	4.24	2	7	2	7	-.09
Male	16	4.56	4.44	2	7	3	7	-.12
Female	5	3.6	3.6	2	6	2	5	.00

The most obvious explanation for these results is that the Treatment group students were asked to take the posttest during exam week, a strain that no doubt affected their motivation to perform well, especially since the GEOPOD assessment score would not affect their grade.

Judging by some of the low scores earned by seniors in the Treatment group (students who were about to graduate), it would be reasonable to assume that that many of these students were not sufficiently engaged in the test to register a realistic score, a score that one might reasonably expect after a full course of instruction related to the test topics. The Comparison group, on the other hand, was asked to take the GEOPOD assessment during the end of the term *before* finals. The only conclusions that can be drawn from this analysis is that the Treatment and Comparison groups appear to be similar in background knowledge at the pretest and that, in the future, testing conditions need to be optimum and procedures need to be standardized in order to gather reliable comparative data. Otherwise, the GEOPOD assessment seems to be performing as intended. The testing results do demonstrate the equivalency of the two groups (treatment and comparison) at the pretest and the test results provide more assurance of the reliability of the instrument.

#### **Exhibit 4: Comparison of Pre and Posttest Scores for Comparison and Treatment Groups**



#### **Student Reactions to the Use of the GEOpod in the Classroom**

In addition to the anecdotal reports on student reactions to the GEOpod technology from the Usability Study conducted in 2011, this evaluator conducted a survey of students who used the technology in the fall term of 2011 and the spring term of 2012. Students who were trained on the GEOpod technology and exposed to this technology during the course of their instruction<sup>8</sup> were asked to respond to questions regarding their impressions of the value and usefulness of the GEOpod in instruction and learning. The survey consisted of 17 items in which students were requested to: (1) respond to demographic questions (e.g. major, college level, gender); (2) describe any challenges encountered in using the system; (3) provide their opinions about the benefits and challenges of using the GEOpod to enhance content learning; (4) suggest content for other GEOpod missions; and (5) comment on whether or not they believed that this technology should be used in science courses at Millersville and at other universities in the future. (See Appendix C for the complete student survey.)

<sup>8</sup> Students had limited exposure to the GEOpod technology in spring term of 2011 and fall term of 2012; The technology was used during only one lab session in each of these terms.

## **Student Demographics**

A combined total of 64 students participated in the survey, 43 in the fall of 2011 and 21 in the spring of 2012. A mix of students took the survey. In the fall of 2011 almost an equal number of sophomore and senior level students took the survey, 25% and 28% respectively. Only 10 juniors (16% of students) and one graduate student (2 %) took the survey at this time. (See Exhibit 5). The majority of students were majoring in Meteorology (75%), followed by students majoring in Earth Sciences (9%), other Sciences (8%), Science Education (6%) and Ocean Sciences (2%). Sixty-four percent (41) of the students were male and 36% (23) were female.

**Exhibit 5: Demographic Information on Students Responding to the Survey in Fall of 2011 and Spring of 2012.**

<b>Demographic Factors</b>	<b>Categories</b>	<b>Number of Students</b>
<b>College Level</b>	Freshman	0 (0%)
	Sophomore	25 (39%)
	Junior	10 (16%)
	Senior	28 (43%)
	Graduate	1 (2%)
<b>Major</b>	Meteorology	48 (75%)
	Earth Sciences	6 (9%)
	Other Sciences (e.g. Physics)	5 (8%)
	Science Education	4 (6%)
	Ocean Sciences	1 (2%)
<b>Gender</b>	Male	41 (64%)
	Female	23 (36%)

## **Students' Prior Experience with 3-D Gaming and Computerized Interactive Data Systems**

Students were asked to report on their prior experience with 3-D gaming or computerized interactive systems in order to determine the effect of this exposure on their perceptions of the ease of use of the GEOpod or their opinions of the value and usefulness of this kind of technology. On the survey students could pick more than one type of technology experience and provide evidence of other related types of experience with interactive systems. Over a third of students reported having experience with 3-D gaming (35%) and an equal amount reported

experience with navigational systems such as Google Earth and Microsoft flight simulation. About a quarter (26%) of students reported using more sophisticated meteorological systems such as McIDAS, IDV, or GEMPAK/GARP. Fewer than six students (6%) responded that they had no experience with any of these computerized systems<sup>9</sup>. (See Exhibit 6)

#### **Exhibit 6: Student Experience with Computerized 3-D and Interactive Systems.**

<b>Computerized and Interactive Systems</b>	<b>Number of Responses Checked (N=102)</b>
3-D Gaming (e.g. Call of Duty, World of War Craft)	36 (35%)
Navigational Systems (e.g. Google Earth, Microsoft Flight Simulator)	35 (34%)
Computerized systems managing complex meteorological data (e.g. <i>GIS, McIDAS, IDV, GEMPAK/GARP</i> )	25 (26%)
No experience in 3-D gaming, navigational systems or computerized systems managing complex Meteorological data	6 (6%)

#### **Student Challenges in Using the GEOpod Technology**

Students were asked to respond to a set of items identifying any challenges they had in using the GEOpod, whether content-related problems or issues with the technology (e.g. ease of use and navigation). The following table (Exhibit 7) lists the student's responses in order of importance. They were able to check off more than one item and also provide additional reasons for challenges, if they had any.

Over a third (39%) of the student respondents indicated that they had no difficulties navigating the GEOpod system. About a fifth of the students (21%) indicated that there were frequent crashes in using GEOpod<sup>10</sup>. A few students (14%) indicated that the system had to be used in a controlled environment in a computer lab where there was an assurance that the computers could handle the program<sup>11</sup>. Few (5) students indicated that they were frustrated with the difficulty of navigating the system (7%). As few as five students (7%) felt that using the GEOpod took time away from the course lecture and coursework or that it disrupted the flow of

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<sup>9</sup> Anecdotal evidence from instructors indicates that those students who had experience with gaming got up and running on the GEOpod faster and recovered faster when they experienced crashes. Overall, however, even students inexperienced in gaming were able to utilize the system fairly easily.

<sup>10</sup> Note that these responses were primarily recorded in fall of 2011 before the technology team made more adjustments to the system. Few students in 2012 indicated that there were frequent crashes on the system.

<sup>11</sup> Students in 2012 who are accustomed to a technologically mobile society, expected to be able to use this sophisticated system on their laptops. The technology team has overcome this hurdle for trials in fall of 2012.

the class (4%). Only one student indicated that the GEOpod had no relevance to the course content and only three students (4%) felt that the content of GEOpod was too difficult. All students agreed that the teachers were able to connect the content of the class with the GEOpod missions.

**Exhibit 7: Student responses regarding challenges in using the GEOpod.** (*Students could indicate more than one response.*)

Challenges with GEOpod	Number of Responses Checked
No difficulties navigating the system	28 (39%)
Frequent crashes	15 (21%)
Had to be used in a controlled lab setting	10 (14%)
Difficult to navigate	5 (7%)
Took time away from lecture/coursework	5 (7%)
Content too difficult	4 (6%)
Disrupted the flow of the class	3 (4%)
No relevance to course content	1 (1%)
Instructor did not connect missions to course content	0 (0%)

### **Student Perceptions of the Usefulness of the GEOpod in Teaching and Learning**

Students were asked to respond to questions regarding the extent to which they felt that using the GEOpod in their coursework enhanced their learning of content. Even after their limited exposure to GEOpod in the classroom, a overwhelming majority of students (75%) responded to this question in the positive; one quarter responded that the GEOpod did not enhance their learning, although some of these students remarked that perhaps after greater exposure and use of the GEOpod they might realize greater learning benefits as the “potential” was there.

Students provided open-ended comments to support their Yes or No statements. Of those who responded “Yes” to the question, the majority felt that the GEOpod was helpful because it was visually compelling (41), some (7) expressed that it gave them a chance to explore patterns and relationships in the data displayed and gain a deeper understanding of the interrelationship among concepts. Still others (5) responded that they enjoyed the active or kinesthetic aspects of the technology (e.g. flying around inside the jet stream and being able to set parameters).

**Students who responded the visual aspects of GEOpod.** Those students who responded to the visually compelling aspects of the GEOpod may actually be visual learners who feel that the technology aided in their understanding of content by allowing them to actually

“see” the phenomena they had been studying. Visual learners often learn best when ideas, data, and concepts are associated with images, demonstrations, and simulations<sup>12</sup>. Sample comments from students who enjoyed the visual aspects of the GEOpod follow:

**Sample comments from students who found the GEOpod missions visually compelling:**

- *It is really hard to visualize what is happening in the atmosphere and GEOpod lets you see it, which really helps you understand the concept better.*
- *It is so fascinating and exciting that we can see/visualize things that are happening in the atmosphere that we never could before.*
- *[GEOpod] let me see in 3-D atmospheric properties that could not be seen in many, if any, other places.*
- *It helped me visualize the structure of winds in the upper atmosphere as well as humidity. I was also able to see how the particles changed as I moved around.*
- *[GEOpod] helped by providing a 3-D visualization of the jet stream. 2-D models were insufficient.*
- *I really liked being able to view the jet stream in 3-D. I got a sense of the size of the jet stream.*
- *I was able to get a 3-D look at a jet stream and see the differences in the wind speeds within the jet itself.*
- *I was able to visualize the temperature of cloud tops more easily and the role of the jet stream in the upper levels.*
- *When looking at the jet stream velocity in a certain [mb] level you could actually see the shape of the jets.*
- *Showing the vertical extent of the strong winds [was helpful].*
- *[GEOpod] helped me see the jet stream as elevated (different from the top down view).*

**Students who responded to the opportunity to detect patterns and relationships in the data.** Some of the comments suggest that students who responded positively to the GEOpod

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<sup>12</sup> For further information about learning styles, see the citation for Howard Gardner on Multiple Intelligences in the reference section.

technology and missions were logical mathematical learners. As Gardner (1999) suggests in his discussion of multiple intelligences, students who are logical/mathematical learners often look for patterns, connections, and relationships among concepts and group information to help them better understand phenomena. These students utilize “systems thinking” in trying to understand connections between parts or concepts and being able to see the bigger picture. Students who utilize this style may naturally be drawn to systems that use simulations and gaming systems like the GEOpod. Many logical mathematical learners naturally seek professions in the sciences, mathematics and computer programming and a system like the GEOpod could have strong appeal for them.

#### **Examples of comments from students using logical mathematical reasoning.**

- *GEOpod is a very useful tool that can help explain difficult concepts and it also gives a bigger view of all the variables going on in the atmosphere at one time.*
- *I think GEOpod is a great idea and can really help people understand the inner workings of the weather.*
- *It helped me understand the flow and paths and winds in the atmosphere.*
- *GEOpod is great at helping people see synoptic maps and connections in layers.*
- *Helped me to visualize a jet stream and helped relate parameters to each other.*
- *Great tool in helping students understand how the atmosphere behaves.*
- *It helped me understand certain topics better. [Isobars] the 3D pressure levels.*
- *I finally understand the magnitude of Vort Max.*

**Students who responded to the kinesthetic aspects of using the GEOpod.** Those students who responded to the physical aspects of the GEOpod may be kinesthetic learners. These learners, also known as tactile learners, are students who learn best by carrying out a physical activity, rather than listening to a lecture or watching a demonstration. Students with a kinesthetic learning style are also commonly known as "do-ers."

#### **Sample comments from students who responded to the GEOpod from a kinesthetic orientation:**

- *I was able to travel through the jet stream and see all the different patterns.*

- *Navigating through the jet stream helped me better understand it.*
- *I like moving through the jet streams. GEOpod helped me visualize and see phenomenon in the atmosphere.*
- *It was nice to be able to fly through the jet stream and see how things changed.*

**Students who did not find the GEOpod helpful.** Comments from students who did not find the GEOpod helpful in learning fell into three distinct categories: (1) Those who actually felt that they needed more time with the system in order to judge its usefulness in their learning; (2) those who didn't feel they understood meteorological concepts well enough to profit from using the system; and (3) those who did not feel that using technology in any way helped increase their understanding. This latter category may also represent a style of learning. These students may already feel that they know the content presented in GEOpod and that the GEOpod offered little in addition to what they already received in more traditional formats from lectures and textbooks. Their comments are below.

#### **Comments from students who did not find the GEOpod helpful.**

##### **Limited use in class:**

- *We didn't use it enough to be significantly impactful.*
- *It would have been nice to spend more time exploring with GEOpod and learning how to use it.*
- *[Needed] more time. I understand it's new, but if we used it more often I would feel more comfortable with it.*
- *Could be better used before and after a topic is taught to deepen learning.*
- *[GEOpod Missions] These should have been used from the beginning of the school year.*
- *[GEOpod] wasn't applied thoroughly in class.*
- *We didn't use it enough to get a deeper understanding of meteorological phenomena.*

### **Lack of background in Meteorology:**

- *I don't feel like I have a strong enough understanding of meteorology to be able to understand it as much as someone in an upper level class.*
- *This was my first meteorology course, which made GEOpod very difficult. I suggest that it be used for only more advanced courses.*

### **Technology not useful:**

- *The GEOpod modules were not very realistic to me. I didn't learn anything new.*
- *It helped me visualize, but not much else.*
- *My level of understanding has not really changed either way.*
- *The computer images did not further explain the topics in a useful way. They were just something to look at. It is a good visualization tool, but not a learning tool.*

### **Suggestions for other topics of changes for the GEOpod**

Students were provided opportunities on the survey to comment on topics they would like to see explored in the future or changes to improve the technology of the GEOpod. Students typically suggested topics for the GEOpod that involved large weather phenomena such as thunderstorms, hurricanes, and tornadoes. While limited, some students did have suggestions for technology changes, such as making the GEOpod internet accessible.

### **Other topics they suggested for GEOpod missions<sup>13</sup>:**

- *Thunderstorm, storms, and tornadoes (17)*
- *Hurricanes and tropical cyclones (6)*
- *Blizzards, snowflakes, and precipitation (4)*
- *Fronts (4)*
- *Cloud formations (3)*
- *Ocean currents (1)*

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<sup>13</sup> The project staff suggest that the types of displays are limited by the GEOpod model. Anything smaller than 160 kilometers cannot be displayed. This becomes an issue of mesoscale vs. synoptic output scale. For instance, thunderstorms and tornadoes are too small a scale to be handled by GEOpod, but hurricanes could be tracked and such synoptic events such as blizzards.

- *Atmospheric composition. (1)*
- *Aurora (1)*
- *Supercells (1)*

### Suggestions for changes to the GEOpod:

- *Use a paddle wheel button to visualize vorticity strength and direction.*
- *Make it an integral part of the curriculum.*
- *Make it Internet accessible.*

When asked if the GEOpod should be used at other universities, 98% of respondents said yes and only four students (6%) said no. This is a testimony to the strong appeal of GEOpod in instruction across a spectrum of students.

### Summary

Overall, it is remarkable to see the overwhelming appeal and support for GEOpod among students, especially given the limited exposure both in fall of 2011 and spring of 2012. This suggests that the GEOpod holds promise if used strategically in classrooms, linking the missions to specific concepts being discussed in the classroom. The data suggest that the GEOpod appeals to the long-stated need for more interactive, visually compelling and less passive instruction in the classroom. Students certainly responded to those aspects of the GEOpod; this technology appears to hold great promise for instruction in the classroom.

## SECTION VI: LESSONS LEARNED

In order to determine the project staff's perceptions of the successes and challenges of the GEOPOD project, the evaluator interviewed the project team on May, 2012 by teleconference. The following topics were addressed on this call:

- Each person's perspective on the major successes or accomplishments of the project;
- Factors that they believed either facilitated or impeded the project;
- Lessons learned from this NSF-funded project for them personally, for the department/college, and/or for the implementation of other funded projects going forward; and
- The extent to which they felt that the GEOpod would be sustained in instruction at Millersville once the project ended.

What follows is a summary of the team's responses to these questions.

## **Major Successes or Accomplishments of the Three-Year GEOPOD project**

There was overall agreement that the project accomplished two of its major goals: (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 and (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.

Project staff agreed that they had produced what could be called a “proof of concept,” that is, an interactive 3-D environment that provides users with the capability of navigating a virtual probe (the GEOpod) through a geophysical data volume while actuating virtual devices, all the while being guided by a tiered instructional design strategy. They felt that they had created a design perspective that would appeal to “net-geners” who are adept at gaming, and motivate them to explore the data volume and take away a better understanding of meteorological concepts and potentially enhance learning and discovery.

In addition to these successes, the staff agreed that there were unexpected outcomes to the project, chief among them being the fact that the undergraduate researchers did a great job of developing the GEOpod technology and that there were many personal and career related lessons linked to their work on this project. There was also general agreement that training was integral to the project and that the team had developed a unique and tested training scenario and that the step by step User’s Guide would be useful to the field.

## **Factors That the Project Staff Believe Either Facilitated or Impeded the Project**

The project staff agreed that the design of the GEOpod system hampered full roll of the GEOpod beyond the confines of a lab environment where computers were available that could support the sophisticated software. The GEOpod is not yet robust or reliable enough to be used on computer equipment that can’t be expected to fully support it. The technology team has overcome this hurdle on some laptops, but the resolution may not be as good as on the computers in the labs. More testing is necessary. The GEOpod requires further testing to be sure that it can be used beyond the confines of the computer lab (e.g. on student laptops and in other venues outside of Millersville). The technology developers had high end systems in mind when designing the GEOpod software; therefore using the GEOpod on systems that don’t meet the requirements for which it was designed could severely test the technology. At this point, there is

no technical support for instructors or students outside of Millersville using the GEOpod technology. The project would need to do a trial run to see how others would use the system, to test it on other systems, and determine those technical issues that might arise and what kind of training and support users would need to use it independently. There was agreement that training is key to using the GEOpod properly.

### **Lessons Learned from this NSF-Funded Project for Staff Personally, for the Department/College, and/or for the Implementation of Other Funded Projects Going Forward**

The original project plan called for the use of the GEOpod with multiple missions in three courses (ESCI 241, 341, and 441) during both the fall of 2011 and spring of 2012. In reality, the GEOpod was used only with students in ESCI 241(Meteorology) in fall of 2011 and in ESCI 444 (Mesoscale Meteorology) in the spring of 2012, and then only at the end of the semester and utilizing just a few of the missions. Dr. Yalda explained that several things hampered full implementation and use of the GEOpod. First, the instructors did not feel the level of confidence with the technology to fully integrate it into their instruction. It takes time and planning to develop the missions<sup>14</sup> and then manage a curriculum and the syllabus that integrates those missions and the technology in a way that supports the course content. Further there were connectivity problems that hampered their confidence that they could fully carry out their instruction with the GEOpod. So preparation time and the comfort level with the technology were the biggest factors hampering implementation. But when they did implement, the students truly valued the GEOpod technology.

Better planning is called for to fully integrate the GEOpod into the coursework. Dr. Yalda will again be testing the technology and the missions this fall, 2012 in a freshman seminar where she will give assignments to students to explore parameters, get familiar with the technology, and look up such things a temperature or pressure fields. Dr. Clark will use it in ESCI 341 (Atmospheric Thermodynamics) to display phenomena the class is studying and have questions embedded in the missions for students to explore. Dr. Sikora will use it in 441(Synoptic Meteorology) in an exploratory mode to explore issues, such as stability, that are often difficult for students.

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<sup>14</sup> All of the missions were not fully developed until late in the spring term of 2012.

For any instructors or students using the GEOpod both within and outside of Millersville, training will be key. For students, one hour or two hours of training is critical to learn the technology and how it relates to the content of the classroom. Instructors will need to learn the technology, become familiar with the missions and the mission builder, and understand how to integrate all of this into appropriate instruction. The GEOpod is a tool, a very effective tool, but it's important to know how and when to use it for maximal learning impact. The question remains, *What is the best instructional integration and use of the GEOpod in the classroom?* Is it best used strategically with 2-3 concepts with the whole class or just in support of students struggling with concepts or wanting to explore concepts on their own? More testing is necessary to learn about the optimal use of the GEOpod. At this point, the GEOpod team plans to use it more in instruction in 2012 and 2013 and to reach out to other colleges to have them try out the system. The team believes that the technology can be adopted in other settings if these institutions have the resources to support it. Towards this end, the project staff is planning to put together a video of the project to send to several other cooperating universities to generate interest and address questions.

The staff shared a few additional insights:

- Being able to bridge the language divide between technology and meteorology was a hurdle for all parties involved. Understanding each other's paradigm was difficult for both the technology and meteorology staff.
- The technology developers agreed that if there was a way to break the technology, the student users would find it (e.g. the plug in to IDV issues). It's difficult to build a bullet proof technology system, but they feel that through user testing they made breakthroughs. Also it's important to know the limitations of the software and to test it on multiple computers and in multiple venues. Again, training is key in avoiding unnecessary errors.

Overall the conclusions of the group were that there was a tremendous effort put forth from the computer science and meteorology departments. They had a highly effective technology team working, a team that produced a system (GEOpod) that has great potential for the field of meteorology and for instruction in the sciences. They look forward to more testing and use in the classroom.

## **SECTION VII: CONCLUSIONS AND RECOMMENDATIONS**

This section presents the evaluator's conclusions and recommendations from the GEOPOD three year project based on the data presented in the sections above. These conclusions and recommendations follow from the goals and objectives of the GEOpod project as laid out in the GEOPOD project plan and reiterated below. The ultimate goals of the **GEOPOD** project were 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 meteorology classroom;
- Provide an instructional design for use in the classroom that complements the GEOpod technology and will excite and motivate students to explore and discover the geophysical realm and deepen their interest in the field; and
- Determine the efficacy of this technology-based approach for undergraduate teaching and learning in the field.

## **CONCLUSIONS**

### **Conclusion 1: Successful Development and Rollout of the GEOpod System**

As evidenced by (1) the conclusions of author of the GEOPOD Usability Study, (2) judgments of instructors who used the GEOpod in their classes, and (3) feedback from students who were exposed to the technology during the Usability Study and in two meteorology classes at Millersville, the GEOpod was successfully designed by Dr. Zoppetti and his research and development team and supported by Drs. Clark and Yalda. Due to the team's diligent design and development work during the first two years of the project, the GEOpod system was fully operational and ready for implementation in selected Meteorology courses in the fall semester of 2011.

While the team continues to refine the system and look for ways to make it compatible with other platforms, the GEOpod was successfully launched during this project period and has proven its potential as a very valuable teaching tool in the field of meteorology. The technology is ready for classroom use and ready to be shared in other instructional venues.

### **Conclusion 2: Successful Development of Instructional Supports that Complement the GEOpod and Aid Users in Effectively Employing the Technology**

In addition to the GEOpod system, other supports have been put in place to reinforce successful implementation of the GEOpod technology in instruction, potentially enhance learning and aid

all other likely users in the field of meteorology. A research and development team member, in collaboration with Dr. Yalda, developed the GEOpod User's Guide which is an invaluable tool for instructors, students and others who will use the system. In addition, Dr. Yalda developed six missions to use with the GEOpod in instruction. These missions are fully developed instructional exercises that will aid instructors in making maximal use of the GEOpod in their courses. In addition to the missions, student research assistant Lindsey Young along with Drs. Yalda and Clark has designed a "mission builder" which will allow instructors to design their own instructional missions that utilize the GEOpod and complement content that they are presenting in their courses.

An assessment instrument that can be used in meteorology classes is also in place and has been tested for validity and reliability. This assessment coupled with the questions included in the mission exercises provides a convenient assessment package for instructors interested in understanding student learning gains following instruction with the GEOpod. A GEOpod project website was also established (<http://csheadnode.cs.millersville.edu/~geopod/index.html>) as an effective online tool to support the use of the GEOpod, make available project documents (e.g. the missions and the User's Guide), presentations, evaluation reports, and links to other relevant websites.

Development of these support structures for the GEOpod is critical as the project moves beyond this funded phase and collaborators begin to integrate this interactive, technology-based approach to instruction into other college courses. This kind of technical support and documentation is key as the GEOPOD project staff begins to introduce the GEOpod to other college instructors in the field of meteorology.

### **Conclusion III: The GEOpod Appeals to a Wide Variety of Students**

Even though the GEOpod was used in a very limited way in two courses at Millersville, student response to the technology was overwhelmingly positive. The interactive 3-D aspect of the technology appealed to students across the board (e.g. those who were familiar with gaming as well as those who had limited experience with this kind sophisticated technology). It was also striking to learn that students were not just "awed" by the visual and interactive aspects of the technology but were able to pinpoint aspects of the technology that aided in their deeper understanding of concepts. This is a technology that has great appeal to "net-geners" and promises to be a promising instructional support in the meteorology instructor's arsenal.

Also, the impact on the student research and design team was profound. 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.

#### **Conclusion IV: Limited Use of the GEOpod in Meteorology Courses**

The GEOpod technology was used in only two Meteorology courses at Millersville and then only at the very end of the term. This limited exposure was not sufficient to judge the impact of the GEOpod technology and instructional missions on student learning. Three overarching questions remain that were not answered by this project: *What is the most effective use of GEOpod in the classroom for instruction?* and *How should instructors use the technology in the classroom to maximize student learning?* *What groups or subgroups of students learn best with the GEOpod?*

Various suggestions for how the GEOpod should be woven into instruction emerged from this study, such as (1) using three or four GEOpod missions in a structured situation with guided instruction throughout a term. This would not only allow students time to become familiar with the technology and its capacity, but also allow them to absorb the content delivered through GEOpod, (2) using the GEOpod in a controlled lab setting, and (3) having students use the technology and missions in a more independent or individualized format, allowing them to explore content that they are either struggling with or want to explore further or even letting them use the mission builder to design their own missions and explore phenomena of interest. It would be useful to the field of meteorology to test each of these methodologies and examine the ultimate effect on student learning. At this point the project has no empirical evidence that the GEOpod has a substantial effect on student learning and limited understanding of those features of the system that are critical for the learning process and why.

### **RECOMMENDATIONS**

#### **Recommendation 1: Further Testing the Efficacy of the GEOpod in Instruction**

The GEOpod technology holds tremendous promise as an effective instructional and learning tool in the study of meteorology. It would be useful at this point if the project team sought additional funding in order to explore the systematic use of the GEOpod in instruction and answer the research questions related to the efficacy of this approach in student learning posed in Conclusion 4. Should the project team receive this funding, a coordinator should be selected and provided a salary or release time to devote time *specifically* to managing the instructional aspects of this project. The project should develop a robust design specifically aimed at examining student use of the GEOpod in several instructional settings. 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 impacted from the use of 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 scenarios where teachers integrate the technology on a regular basis to explore concepts in their classes.

#### **Recommendation 2: Expanding the GEOpod Project to Other Venues**

As evidenced by audience reaction to the presentations on the GEOpod technology at two meetings of American Meteorological Society, there is enthusiasm about employing this technology at other universities and in other educational venues beyond Millersville. It would be helpful for the project team to begin to explore interest at other institutions and to bring some of these institutions in as collaborators in further testing the GEOpod in the classroom. Since adapting this kind of project in another setting would require careful planning and resources,

these efforts should be considered carefully at the beginning. At the very least it would be important to make the GEOpod technology, the missions, the User's Guide, and standardized procedures for student instruction and testing available to interested parties. Any effort to expand the reach of the project should be accompanied with specific plans to provide technical support and training to collaborating partners. This collaboration could form the basis of the second iteration of the project yielding important information to the field.

### **Recommendation 3: Training and Support for Future Users of the GEOpod**

Should instructors at other universities want to use this technology, several supports will need to be in place. First, the need for training for those who wish to adopt this technology cannot be overstated. As mentioned in the conclusions of the Usability Study, training for students and instructors is important as it enables them to easily use the GEOpod system and maximize their instruction and learning with 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. Second, during training, instructors will begin to understand what is involved in fully implementing and using the technology in the classroom for maximum benefit to students and understand the kind of planning that needs to be in place prior to instruction. Third, access to follow up technical assistance needs to be in place; technical assistance that allows instructors to feel comfortable asking questions and seeking solutions to issues that arise in 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 (Stevens, 2004). Any expansion of the GEOPOD project to other collaborators at other universities and venues would need to include a high level of support for instructors who wish to adopt or adapt this technology.

## **SECTION VIII: REFERENCES**

Gallus, W.A., Cervato, C., Cruz-Neira, C., Faidley, G., and Heer, R. (2005). Learning storm dynamics with a virtual thunderstorm. *Bulletin of the American Meteorological Society*, 162-163.

Gardner, H. (1999). Intelligence reframed: Multiple intelligence for the 21<sup>st</sup> century. New York, NY: Basic Books.

How People Learn. (2000). National Research Council Commission on Behavioral and Social Sciences and Education. National Academy Press. Washington, DC.

Kelly, H., (2005). Challenges and Opportunities in Game-Based Learning Environments. Retrieved April 15, 2006. <http://www.nae.edu/nae/caseecomnew.nsf/weblinks>.

Liffick, B. W. (2011). GEOPOD project usability study analysis. (<http://csheadnode.cs.millersville.edu/~geopod/index.html>).

Mackin, K.J. (2010) GEOPOD evaluation report, Phase I: GEOpod design and development.  
<http://csheadnode.cs.millersville.edu/~geopod/index.html>

Mackin, K.J. (2011) GEOPOD evaluation report, Phase II: GEOpod implementation.  
<http://csheadnode.cs.millersville.edu/~geopod/index.html>

Oblinger, D. (2004). The Next Generation of Educational Engagement. *Journal of Interactive Media in Education*. Special Issue on the Educational Semantic Web. 8.

Presnyk, M. (2003). Digital Game Based Learning. Exploring the Digital Generation. *Educational Technology*, US. Department of Education.

Stevens, R.J. (2004). Why do educational innovations come and go? What do we know? What can we do? *Teaching and Teacher Education*, Vol. 20, (4), pages 386-396.

The Learning Federation Project, 2003. Retrieved March 1, 2007.

<http://www.thelearningfederation.edu.au/tlf2>

## **IX: APPENDICES**

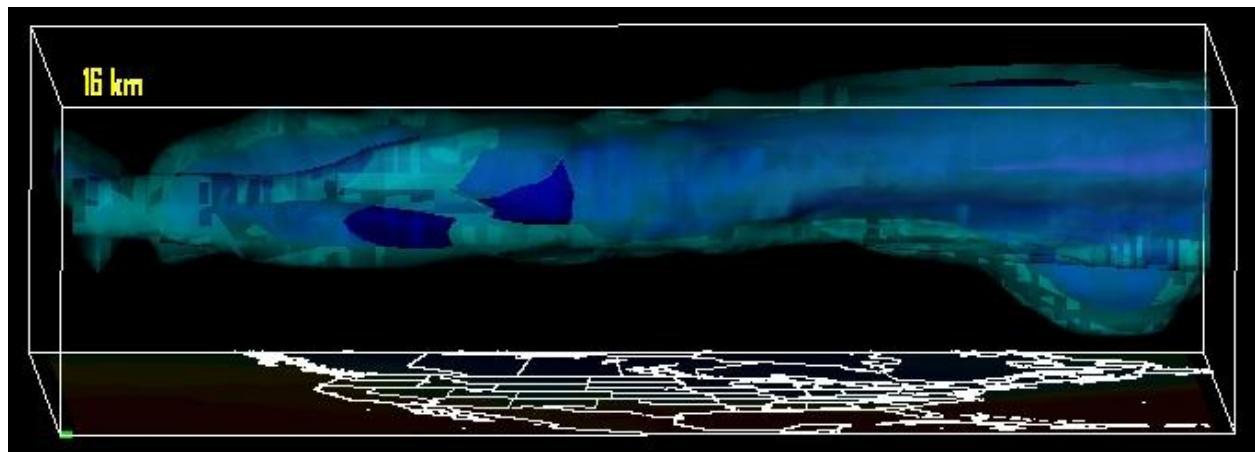
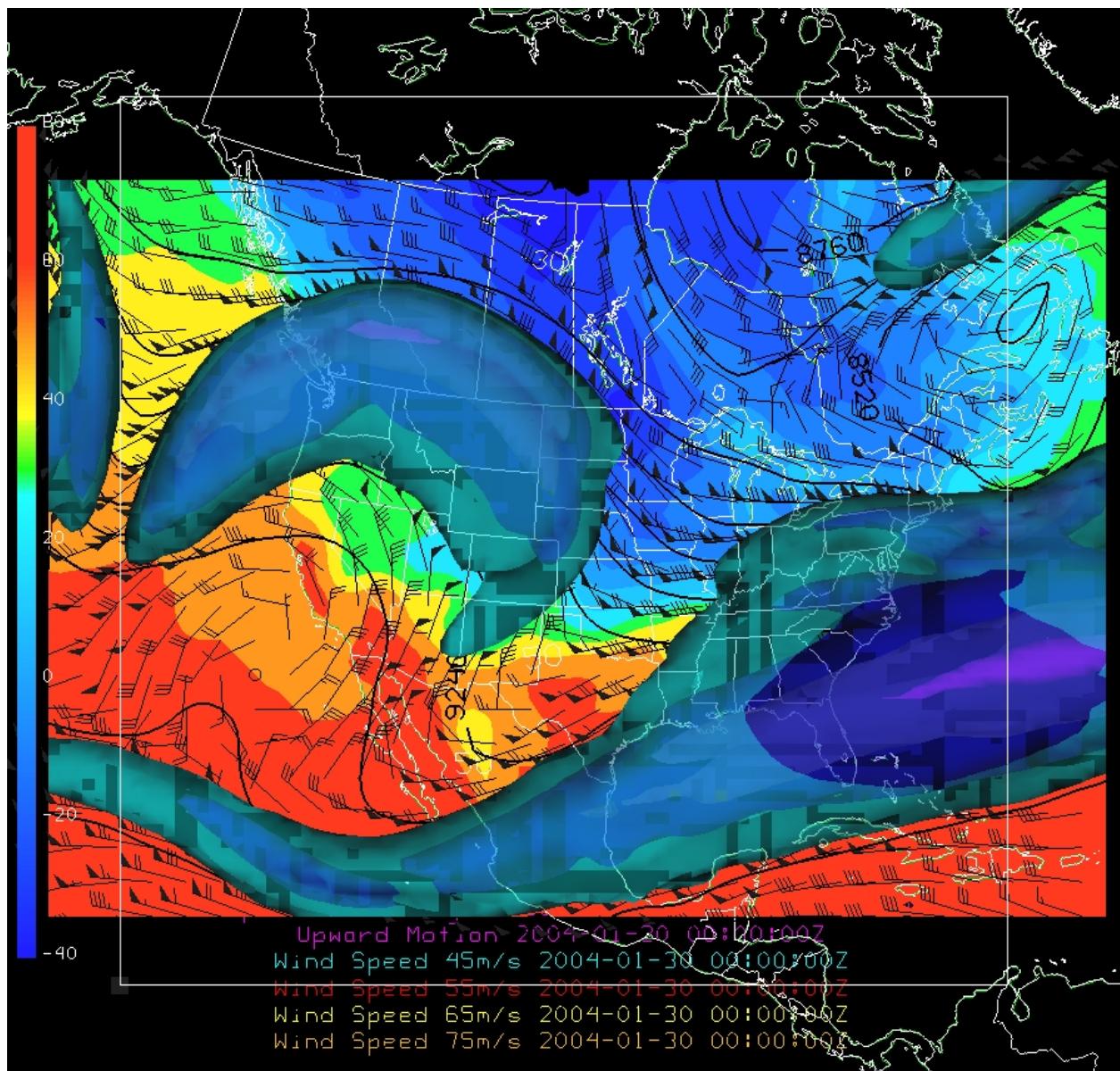
## APPENDIX A: Mission Excerpt: GEOPOD Exploring the Jet Stream

### Mission: Exploring the Jet Stream

**Definition:** jet stream—relatively strong winds concentrated within a narrow stream in the atmosphere.

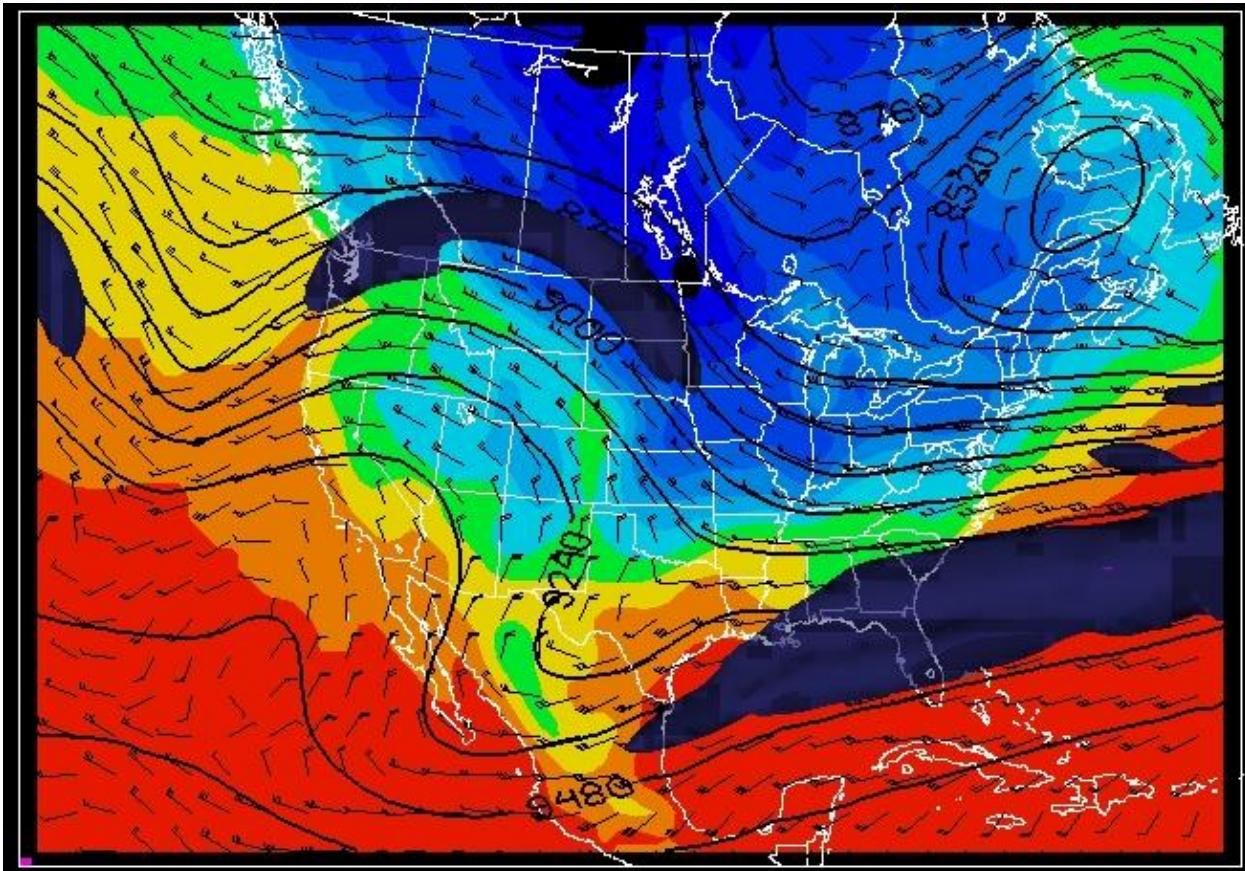
While this term may be applied to any such stream regardless of direction (including vertical), it is coming more and more to mean only a quasi-horizontal jet stream of maximum winds embedded in the midlatitude westerlies, and concentrated in the high troposphere. The question of the maintenance of the jet stream is a cardinal problem of theoretical meteorology. Two such jet streams are sometimes distinguished. The predominant one, the polar-front jet stream, is associated with the polar front of middle and upper-middle latitudes. Very loosely, it may be said to extend around the hemisphere, but, like the polar front, it is discontinuous and varies greatly from day to day. A subtropical jet stream is found, at some longitudes, between 20° and 30° latitude and is strongest off the Asian coast. Currently, in the analysis of upper-level charts, a jet stream is indicated wherever it is reliably determined that the wind speed equals or exceeds 50 knots.

The image below is the polar jet stream *as isosurface* of wind speed at 45, 55, 65, and 75 m/s. Also plotted colored contours of surface temperatures, black contours of 300 mb geopotential heights with an interval of 120m, and 300 mb wind barbs. The contours of surface temperature illustrate the polar jet stream's effect on surface temperature. The 300 mb geopotential height and wind barbs are to exemplify the polar jet stream's effect on the upper-level ridge and trough patterns as well as the direction of the polar jet stream (west to east).



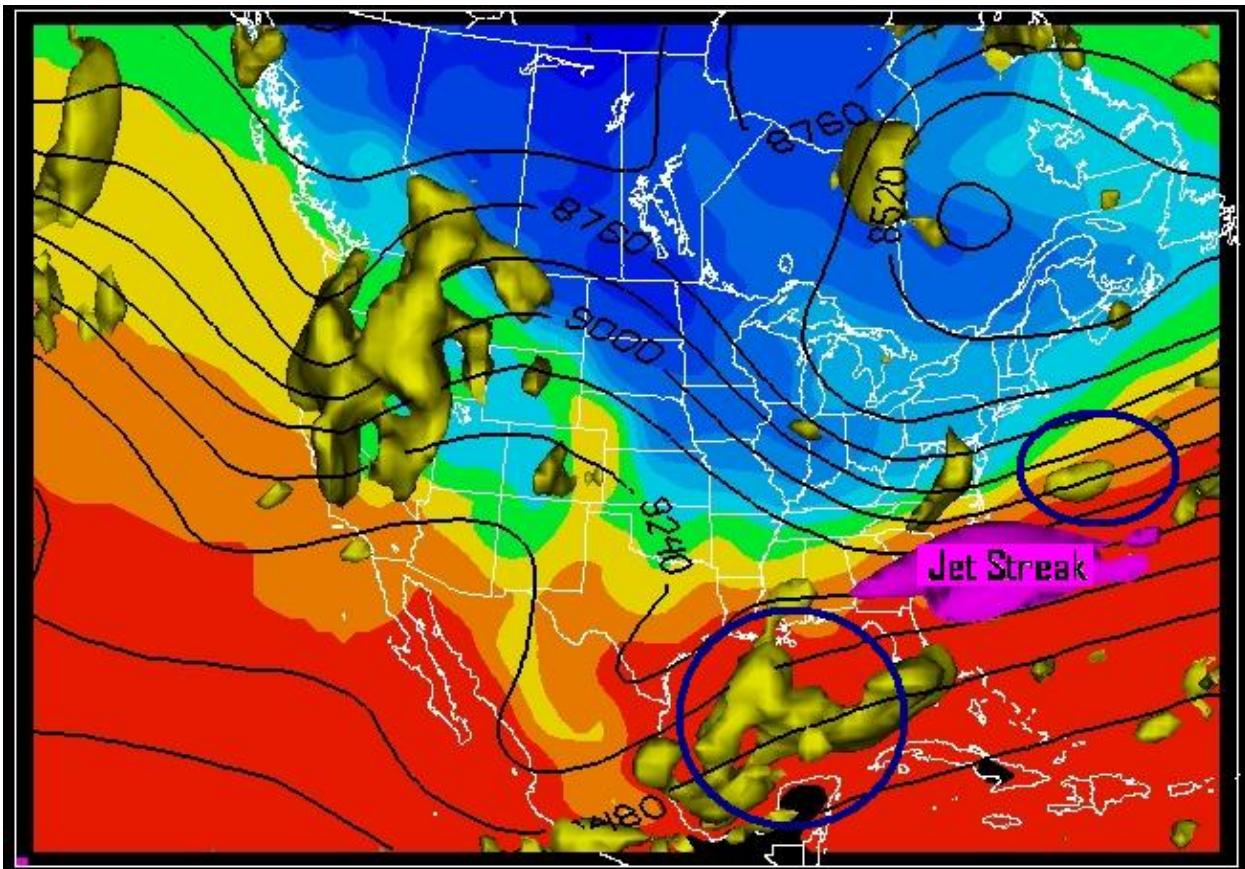
This image shows a view of the jet stream from the ground to 16 km.

**Polar Jet Stream:**



Looking at the 300 mb pressure and surface temperature, notice the upper-level ridge in the western part of the country and the trough in the eastern part of the country. Note that the western states are experiencing warmer temperatures than the eastern states. Also, note that the polar jet stream appears to be in the area of the largest surface temperature gradients and where the 300 mb geopotential height contours are tightest, making it more important to forecasters than the sub-tropical jet stream. During the winter months, the surface temperature gradients are strongest and farthest south, causing the polar jet stream to be stronger in the winter than the summer.

**Jet Steaks:**



The image has an isosurface of 75 m/s winds (magenta) and upward motion (yellow). Pay close attention to the areas of upward motion circled in blue because these areas support the development of storm systems. These regions of upward motion are due to an imbalance between the pressure gradient acceleration and coriolis acceleration at the entrance and exit region of the jet streak .

#### Purpose of this exercise:

The purpose of this exercise is to explore the 3-D structure of the jet stream. We will deploy the Geopod to navigate through the jet stream, explore its horizontal and vertical structure, and see the variability within its structure, and explain and identify the role of the polar jet stream in weather forecasting. The structure of the jet stream is examined through the use of geopotential heights and wind speed variability.

#### Geopotential height:

**geopotential height**—The height of a given point in the atmosphere in units proportional to the potential energy of unit mass (**geopotential**) at this height relative to sea level.

The relation, in SI units, between the geopotential height  $Z$  and the geometric height  $z$  is

$$Z = \frac{1}{980} \int_0^z g dz',$$

where  $g$  is the acceleration of gravity, so that the two heights are numerically interchangeable for most meteorological purposes. Also, one geopotential meter is equal to 0.98 dynamic meter.

#### Wind speed:

**wind speed—Ratio of the distance covered by the air to the time taken to cover it.**

**The instantaneous speed corresponds to the case of an infinitely small time interval. The mean speed corresponds to the case of a finite time interval. It is one component of wind velocity, the other being wind direction).**

**Exploration:**

1. Load Geopod (from the start button, load IDV 3.0b1.
2. From the dashboard, click on Data Choosers
3. From the side menu on the far left hand side, select catalogs
4. Select Unidata IDD model data
5. Select UCAR (motherlode)
6. Select North American Model (NAM)
7. Select NCEP NAM CONUS 80 km
8. Select latest NCEP NAM CONUS 80 km
9. Click on “Add Source” button at the bottom center
10. In the left hand side window under “fields”, select 3D grid
11. Expand 3D, Select u-wind at isobaric
12. In the right hand side window, expand 3D surface
13. <control> isosurface and Geopod (be sure that both are highlighted)
14. Click off “Use Default”, and select the first time listed
15. Click on “Create Display” button
16. You should be able to see the Geopod window with the u-wind component
17. Notice that the bottom right hand corner shows you latitude, longitude, and altitude, adjust the latitude to be 40 and the longitude to be -100 so that you are centered over the United States.
18. Use the mouse and the control buttons to get a 2D view of the map and the jet above the map (w: forward; s:backward; a: left; d: right; f:up; c: down; r: reset and takes you back to your original view)
19. Go back to the dashboard, you should be able to see the color bar that shows the range of the wind speeds and a box where you can enter the “Isosurface value”, enter 30. You can also enter higher wind speed values to see the parts of the u-wind component that have these higher wind speeds.
20. For this exercise, enter 30 in the box for the isosurface value in the dashboard
21. Hit r to reset, then use d to move right until you can see the opening of the wind tunnel; you may have to use the other control buttons to adjust and find the openings.
22. Look at the altitude button and notice your altitude.

23. Use the w button to be sure that you are inside the box and now you should be able to see the wind speed changing as you go through the wind tube.
24. You can now bring in the v-component of the wind and notice the changes as you go through the wind tubes.

**Questions:**

1. **Where do the highest winds in the jet stream seem to form in relation to temperature and pressure?**
2. **Where are jet streaks usually found?**
3. **Why is the left exit region of a jet streak a region of upward motion?**
4. **Explain the relationship between the polar jet stream, upper-level ridge and trough patterns.**
5. **Describe the characteristics of a jet stream. Be sure to mention elevation, direction, and the effect a jet stream has on upper-level pressure patterns.**

## APPENDIX B: Instructor Log

**Millersville University  
GEOpod Project  
Instructor Weekly Log**

Professor Name: \_\_\_\_\_ Date (Project Week Ending Friday): \_\_\_\_\_

*Check if no GEOpod Modules were used this week. Please specify reason why:*

GEOpod Modules Used This Week	Instructional Application	Student Reactions	Additional Materials Used	Instructor Feedback
<p><i>Check all GEOpod modules used this week.</i></p> <p><input type="checkbox"/> Basic Kinematics of Fluids</p> <p><input type="checkbox"/> Relationship between Thermodynamic and Kinematic fluids</p> <p><input type="checkbox"/> Cloud Microphysics</p> <p><input type="checkbox"/> Nature of Ageostrophic Wind</p>	<p><i>How was the GEOpod module used to support instruction? (Check all that apply)</i></p> <p><input type="checkbox"/> Used in a laboratory setting</p> <p><input type="checkbox"/> Used to support lecture</p> <p><input type="checkbox"/> Used for student small-group (or individual) projects</p> <p><input type="checkbox"/> Used in conjunction with other meteorological websites</p> <p><input type="checkbox"/> Used to demonstrate technology to other students/professors or visitors</p> <p><input type="checkbox"/> Used to demonstrate technology to groups/schools <u>outside of the university</u>.</p> <p><input type="checkbox"/> Other: (Specify):_____</p>	<p><i>Briefly describe PRIMARY student reactions to the "Modules/Mission s" (pros and cons). (e.g. increased motivation for topic; created confusion; encouraged questions/discussion; promoted further use of meteorological data, etc.).</i></p>	<p><i>Instructional materials used in conjunction with these GEOpod modules. (Check all that were used this week).</i></p>	<p><b>Please comment on the benefits and/or challenges of using this GEOpod module in instruction. (Specify title of module(s)/missions before each comment.)</b></p> <p><b>Please provide your opinion regarding students' ability to learn concepts/content from using the GEOPOD. (e.g. did it assist/hamper learning?) Give examples of enhanced student learning, if any.</b></p> <p>This module (title: _____) enhanced my instruction.  <input type="checkbox"/> Yes    <input type="checkbox"/> No</p> <p>I would use this module (title: _____) again in instruction.    <input type="checkbox"/> Yes    <input type="checkbox"/> No</p>

## **Appendix C: Student Survey**

### **Millersville University GEOPOD Project Student Survey**

During the past semester your instructor introduced you to one or more of the GEOpod missions to explore meteorology-related theories, concepts, and phenomena in your course. In order to better understand the impact of the use of the GEOpod on your learning, we are asking you to complete the following brief survey.

Your candid responses will greatly inform any future development and use of these GEOpod missions. We are eager to hear student voices. ***All responses are anonymous and will be kept confidential. No respondent names will be used or identified in any project reports.***

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**First, please tell us a little about yourself and then respond to the following questions based on your experience with the GEOpod missions used in your courses.**

**1. Please indicate your college level during spring term, 2012. (Check one.)**

- Freshman     Sophomore     Junior     Senior     Graduate

**2. Gender (Check one.)     Male               Female**

**3. Please indicate your major (Check one.)**

Meteorology

Ocean Sciences

Earth Sciences

Science Education

Other Sciences (e.g. Physics, Chemistry, Mathematics, Computer Science, etc.)

Other (Please specify): \_\_\_\_\_

**4. From the list of GEOpod missions listed below, please check each of the missions used in your course this term. (Check all that apply.)**

- Fronts:** Exploring the 3-D structure and location of a cold front; exploring the locations of fronts.
- Jet Stream:** Exploring the 3-D structure of the jet stream. Navigating through the jet stream to explore the horizontal and vertical structure and the connection to the formation of storm systems.
- Constant Pressure Surfaces:** Exploring 3-D structure of constant pressure surfaces and the connection to geopotential height variability.
- Thermodynamic Structure and Stability:** Examining the thermodynamic structure of the atmosphere and stability parameters.
- Other (Please specify):** \_\_\_\_\_

5. Who introduced or led you through the GEOpod missions used in your courses? (*Check all that apply.*)

- No introduction; I navigated the site myself.
- The course or lab instructor
- A teaching assistant
- A computer lab technology assistant
- Another student in the course
- Other (Please specify): \_\_\_\_\_

6. How were the missions used in your courses? (*Check all that apply.*)

- Instructors used them to support a lecture and/or illustrate a concept or phenomenon.
- Instructors used them in a laboratory or computer lab setting.
- Students used them in small group projects.
- Individual students used them independently to explore a concept further.
- Other (Please specify): \_\_\_\_\_

7. Did you participate in any technology training on the GEOpod system and functionality prior to using the GEOpod in class (e.g. loading the IDV dataset, navigating the GEOpod, understanding how to use features like dropsondes, the particle imager, etc.)? (*Check one*).

Yes

No

If *Yes*, please explain elements of this technology training that were useful or not useful to you.

If *No*, how did you learn about the technological aspects of the GEOpod system and its functionality?

8. Did you receive any training on the content and purpose of the GEOpod missions prior to using the GEOpod technology in class (e.g. Fronts, Jet Stream, Constant Pressure Surfaces, or Thermodynamic Structure and Stability)? (*Check one*.)

Yes

No

If *Yes*, please explain elements of this GEOpod content and missions training that were useful or not useful to you.

If *No*, how did you learn about the GEOpod content and missions and any possible relevance to your coursework?

9. Did you receive any technical assistance from any of the following sources *while using the GEOpod in your class*?

No one assisted me. I used the GEOpod independently.

Someone from the IT lab assisted me.

My instructor assisted me.

Other students in the class assisted me.

Other (Please specify): \_\_\_\_\_

10. In your opinion, what were the learning benefits of using the GEOpod missions in your course? (*Check all that apply*.)

- I *did not* experience any learning benefits from using the GEOpod mission(s).
- Using the GEOpod technology helped me better visualize a phenomenon or a theoretical or abstract concept we were studying in class.
- Using the GEOpod helped me gain a deeper understanding of a phenomenon and/or concept we were studying in class.
- Through the use of the GEOpod I was better able to make estimates or predictions about phenomena (e.g. to explain what would occur as a result of stability changes).
- Other learning benefits of using the GEOpod (Please specify): \_\_\_\_\_

11. In your opinion, were there any motivational benefits to using the GEOpod missions in your course? (*Check all that apply.*)

- The GEOpod technology or missions *did not* affect my motivation to learn more about meteorology or science in general.
- As a result of using the GEOpod missions, I was more motivated to ask questions and/or further engage in classroom or online discussions.
- As a result of using the GEOpod missions, I was more motivated to explore a phenomenon or concept.
- Using the GEOpod missions in class has given me confidence to possibly explore other sophisticated computerized systems that utilize complex meteorological data.
- Other motivational benefits of using the GEOpod (Please specify): \_\_\_\_\_

12. Did your instructor encourage you to use any of the following resources to extend your understanding of concepts you explored through the GEOpod? (*Check all that apply.*)

- No other resources were suggested by my instructor to expand on concepts explored through the GEOpod.
- Meteorology websites or print texts. Please list: \_\_\_\_\_
- Other data visualization software packages? Please list: \_\_\_\_\_
- Other (Please specify): \_\_\_\_\_

13. Were there any challenges that you encountered in using the GEOpod missions? (*Check all that apply.*)

- No difficulties or challenges were encountered in navigating or using the GEOpod missions.
- The GEOpod system had to be used in a controlled lab setting *only*.
- I experienced frequent crashes when using the GEOpod system.
- The GEOpod system navigational instructions were too complex.
- The content of the GEOpod missions was difficult to understand.
- Use of GEOpod missions took time away from the lecture or course work.
- Use of GEOpod missions disrupted the flow of the class.
- GEOpod missions weren't relevant to the class content.
- Other (Please specify:) \_\_\_\_\_

14. In your opinion, did any of the GEOpod missions enhance your understanding of a specific concept or phenomenon in any *significant* way? (Check one.)

Yes

No

**If Yes,** Please give an example of how the use of a GEOpod mission affected your learning (e.g., clarified misconceptions, deepened understanding, etc.)

**If No,** Please explain why you think these GEOpod missions *have not been useful* in deepening your understanding of concepts or phenomena in the atmospheric sciences.

15. What other concepts or phenomena would you like to explore using the GEOpod technology?

16. Would you recommend that other universities incorporate the use of the GEOpod technology or missions in their relevant science courses?

Yes

No

17. In your opinion, what are the *potential* uses of the GEOpod for meteorology students or the field as a whole?

18. Is there anything else you would like to tell us about your experience with the GEOpod technology?