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GEOPAD: TABLET PC-ENABLED FIELD SCIENCE EDUCATION

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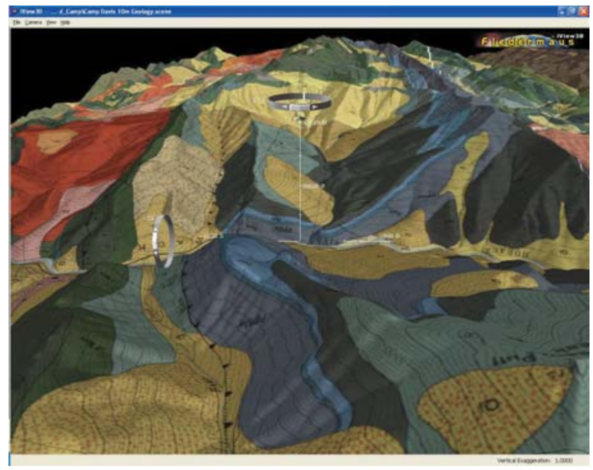


1. ABSTRACT

Over the past three years we have successfully incorporated and evaluated the use of GeoPads in field geology courses offered at the University of Michigan's Camp Davis, near Jackson, WY; a GeoPad is a ruggedized Tablet PC equipped with Geographic Information System (GIS), Global Positioning System (GPS), wireless networking, electronic notebook and other pertinent software. The use of GeoPads has significantly enhanced our field exercises and excursions, for both students and instructors. For example, using GeoPads to teach field geology not only supports the traditional approaches and advantages of field instruction, but also offers important benefits in the development of students' spatial reasoning skills. Students are able to record observations and directly create geologic maps in the field, using a combination of pen-enabled GIS tightly integrated with a digital field notebook. The use of intuitive, free-hand data-entry is a crucial advantage afforded by the Tablet PC. Overall, this arrangement permits students to record, analyze, and manipulate their data in multiple contexts and representations – while still in the field – using both traditional 2-D map views, as well as richer 3-D contexts. Such enhancements provide students with powerful exploratory tools that aid the development of spatial reasoning skills, allowing more intuitive interactions with 2-D representations of our 3-D world. Additionally, GIS-based mapping enables better error-detection, through immediate interaction with current observations in the context of both supporting data (*e.g.*, topographic maps, aerial photos) and students' ongoing observations. This approach also provides students

with experience using tools that are increasingly relevant to their future academic or professional careers.

The approach described herein is easily adoptable through its use of readily-available, off-the-shelf Information Technology (IT). It is also generally applicable to education and research in many traditionally non-IT-savvy science domains, in addition to geology, such as archeology, biology, sociology, natural resources, and environmental sciences.

2. PROBLEM STATEMENT AND CONTEXT

Fieldwork is a cornerstone of many scientific disciplines and a field course – often taught at a location remote to a university's campus and IT infrastructure – is a common undergraduate degree requirement in such programs. Fieldwork itself is generally the first-step in the scientific process of gathering, analyzing, and interpreting data. Whereas subsequent steps are typically accomplished once one has left the field, providing in-the-field access to all such capabilities significantly enhances educational and scientific practices. GeoPad accomplishes this through the use of standard, commodity hardware and software and through the development of best-practices that meet the demanding needs of the field student, instructor, and researcher.

Our initial application of the GeoPad has focused on enhancing three common activities in our senior-level field geology course. These activities have direct corollaries in most field science curricula:

- Mapping – facilitate development of spatial reasoning skills via powerful, intuitive capabilities for in-the-field data entry, visualization, analysis, and interpretation in both 2-D and 3-D representations.
- Field-Trips – enrich the overall field-trip experience by providing in-the-field access to a broad, relevant collection of supplemental materials.
- Field-Based Exercises – enhance the learning opportunities afforded by field-based exercises through support for real-time planning and decision making based on in-the-field data collection, analysis, and interpretation.

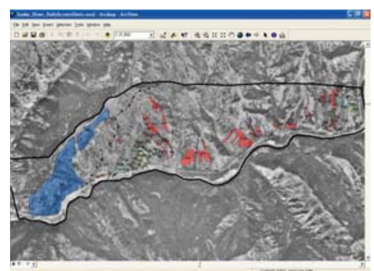
3. SOLUTION EMPLOYED

Continuing innovation in IT, especially in the form of increasing performance and portability, improved haptic interfaces, and advancements in GIS and visualization software, enable in-the-field, real-time access to powerful data collection, analysis, visualization, and interpretation tools. The benefits of these innovations, however, can only be realized on a broad basis when the IT reaches a level of maturity at which users can easily employ it to enhance their learning experience and scientific activities, rather than the IT itself being a primary focus of the curriculum or a constraint on field activities.

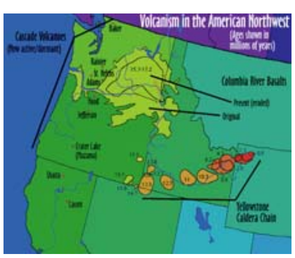
We envision GeoPad as novel combination of these technologies that strives for that level of maturity. Generally speaking, GeoPad is just a short-hand term for a generic concept built from readily-available, off-the-shelf hardware and software; a ruggedized Tablet PC incorporating technologies such as, GIS, GPS, wireless networking, digital imagery, microphone-headset, and other supporting applications and technologies for gathering and working

with spatially-referenced data. In 2005, our typical GeoPad configuration consisted of an Xplore Technologies iX104C2AV (Pentium M733-1.1GHz, 1GB RAM, 30GB disk, and integrated GPS and WiFi) loaded with ArcGIS 9.0, Microsoft Office 2003 (including OneNote), Stereonet 1.2.0, and AdobeReader, and a USB flash drive for in-the-field backups. Students also installed their own applications, such as iTunes, IM clients, and digital camera software.

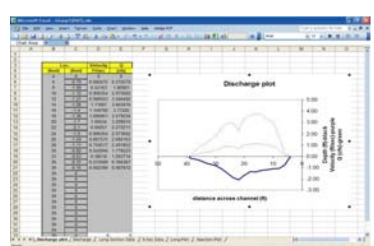
The Geopad-based pedagogical approach addresses the typical needs for field-mapping, field-trip, and field-based exercises via several key, integrated capabilities: (1) digital field notebook, (2) pen-enabled GIS, (3) portable reference shelf, and (4) general data collection and analysis. The digital field notebook capability is implemented using Microsoft OneNote. It enables students to write down notes and make sketches using the Tablet PC stylus, just as they would interact with a traditional paper notebook. The benefit, however, comes from the additional functionality OneNote offers, including drag-and-drop re-organization of information, insertion of arbitrary white-space, and a simple and intuitive suite of writing and drawing tools. Perhaps most importantly, however, it offers the ability to screen-clip, annotate and organize information as needed from other sources (*e.g.*, images from a digital camera, figures from papers, a section of the map a student is working on in GIS).



The pen-enabled GIS mapping approach uses ArcMap and ArcScene, components of ESRI's ArcGIS suite. Like the digital field notebook, ArcMap builds on the intuitive use of the stylus to facilitate familiar paper-based activities. It significantly improves the experience, however, by enabling students to interact and visualize data in ways not possible using traditional paper-based methods, including transparent layering of multiple data-sets, zooming and panning to work more easily and seamlessly with data at multiple scales, and 3-D visualization (ArcScene). In addition, data collection errors are reduced through the use of situation-specific interfaces and the immediate feedback of cartographic symbology. The latter also serves to enhance the readability of a field or rough map, diminishing another potential source of error.



Access to supplemental information, without the need for carrying bulky paper materials on all-day hikes or accessing them in a cramped vehicle, is achieved by storing electronic versions of field guides, figures, maps, photos, *etc*. on the GeoPad. It is important to organize this information in a useful manner and provide search capabilities for students to find relevant information quickly and intuitively. Also, when combined with the screen-clipping capabilities of OneNote, students can easily interact with, annotate, and organize this information in their own learning context.



In-the-field data collection and analysis is achieved through the use of familiar applications, such as Excel and ArcMap. Such capabilities significantly enhance the educational opportunities afforded by field-based exercises in several ways: they permit students to plan and make decisions based on interpretations of data (*e.g.*, where to go next to collect additional data), it allows students to detect errors while still in the region of interest and correct them, and it enables students to explore and evaluate their data – while gathering the underlying field observations – without the need to retreat to a classroom and temporally and spatially disconnect the observation and interpretation activities.

4. EVALUATION

For the past three summers we have employed interviews and anonymous surveys in evaluating the integration of GeoPads in the curriculum of our senior-level field geology course (GS-440). During 2005 our evaluation efforts expanded to include an independent, external evaluation team, composed of science education specialists from the University of Michigan, School of Education. The latter effort also included an assessment of the development of students' spatial reasoning skills in the context of geologic maps and figures. Quantitative evaluation in this environment is challenging, however, as enrollment in field courses are traditionally low; GS-440 typically has only 10-20 students.

Our own interviews and surveys found that students were overwhelmingly positive about their experience; for example, when asked, "How would you rate your overall experience using the GeoPads?" they responded with "excellent" (average of 3.9 on a 4-point scale.) Instructors were similarly pleased with the use of GeoPads. In general, any negative comments or experiences have been technical or logistical in nature, rather than pedagogical. This included issues such as difficulty viewing the display in direct sunlight, not enough GeoPads for every student the first couple years (which left students feeling frustrated switching back to traditional paper methods), and occasional software glitches. The continuing evolution of technology and the availability of additional equipment have helped address these issues.

The School of Education team similarly found that students had a very positive experience. Furthermore, they determined that this outcome was based primarily on the enhanced capabilities of the GeoPad. There is always the possibility that apparent effects of educational innovations receive a temporary benefit from the perceived novelty of the approach, especially when dealing with new technologies. Field observations and interviews, however, indicate that student reactions were based more on utility considerations, rather than the novelty of the technology. In the interviews, students routinely drew comparisons between the GeoPad and traditional map-boards used in earlier field assignments on the basis of enhanced capability, as opposed to convenience issues (*e.g.*, carrying Tablet PCs rather than map-boards) and coolness factors.

The GeoPad capabilities students appreciated most included the ability to overlay mapping elements to enhance visualization of both location and identification of geologic features. Students made regular mention of how the general capabilities of GeoPad enhanced their ability to see – to visualize – the different geologic structures they were mapping using the Tablet PC stylus.

Students did have a number of issues with the stability of the technologies inherent in GeoPad. Although these issues were reduced and nearly eliminated by the end of the field experience, student work was routinely interrupted by intermittent hardware and software failures. In querying students about these issues, it was interesting to observe that they took these challenges as matter of course. Rather than attaching them to limitations of the GeoPad, students viewed this as a standard – and unavoidable – complication of using computers in any setting.

This reinforces the notion that students are not reacting (positively or negatively) to the novelty aspect of GeoPad, but rather positively to the capabilities associated with it.

A pre- and post- test of student spatial-reasoning skills was also administered to the 10 students enrolled in GS-440 during 2005. The results of this assessment indicate a small improvement in students' overall spatial reasoning abilities, but at a less than statistically significant level. Examination of responses to individual questions, however, indicates that students did exhibit statistically significant improvements in specific spatial-reasoning skills associated with the visualization and interpretation of geologic structures, such as understanding fold and bedding plane geometries and reconstruction of features spatially distorted through geologic processes. With the limited sample size and lack of a control group, however, it is not appropriate to solely attribute this improvement to the integration of GeoPads in the curriculum.

5. FUTURE WORK

GeoPad demonstrates the important educational benefits in integrating innovative IT in field geology education. Being a generic approach and given similar needs, it is also directly and readily applicable to other field sciences, and we plan to evaluate its use in other fields. We also plan to revise and improve our spatial reasoning assessment for use in future years and an effort is being made to recruit participants from similar field geology courses at other institutions in order to increase our sample size.

Our future plans also include evaluating the educational benefits of new and exciting technologies, such as: 3D visualization – tighter integration and use of 3D visualization to facilitate students' development of spatial reasoning skills, including stereoscopic 3D; voice recognition – freeing up the user's hands from operational tasks enhances the usability of the GeoPad; particularly when the field activities themselves demand hands-on interaction (*e.g.*, using a compass or rock hammer); digital photography – incorporating images directly into the notebook or onto maps to improve documentation and support richer discussions; Internet access – provide students with real-time access to on-line databases (*e.g.*, USGS Real-Time Stream Gauge Data) and search services (*e.g.*, Google); collaborative discussions – enhance field trip activities through conferencing, ala Microsoft NetMeeting, between field vehicles during trips.

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6. ADDITIONAL RESOURCES

Further information on the GeoPad project is available at http://geopad.org.

7. ACKNOWLEDGEMENTS

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