ACS Reform of Introductory Science Courses for Non-Majors Course Mini-grants
This Program is supported by the W.M. Keck Foundation of Los Angeles

Assessment of Conceptest Questioning and Electronic Student Response Technology in the Small School Introductory Geosciences Classroom: Do these Methods Really Help Non-Science Students Learn?

Submitted by **Lisa Greer**

Assistant Professor
Geology Department
Washington and Lee University
Lexington, VA 24450
(540) 458-8870 (W) (540) 458-8142 (Fax) greerl@wlu.edu

Submission Category: Course/Learning Activity Assessment, Redesign, and Implementation

Date of Submission: March 1, 2006

Proposed Grant Period: June 1, 2006 - June 1, 2007

Signature of Applicant ________________

Signature of Department Chair ________________

Signature of Chief Academic Officer ________________

Project Summary

The combination of pedagogically sound Conceptest questioning and electronic student response technology (SRT) use in the introductory science classroom is thought to provide non-science major students with an effective method for processing and retaining science concepts and content. Conceptests are conceptual multiple choice questions that can be presented in class with or without SRT. Recent implementation in large classroom settings has demonstrated that SRT and Conceptests may offer effective means of introducing active learning into these classes. It is less clear whether SRT can be useful in smaller geoscience classrooms or liberal arts environments where interaction and engagement are thought to be the norm. It is also unclear whether SRT actually *enhances student comprehension and appreciation of scientific principles*.

This proposal requests funding for the implementation and assessment of SRT Conceptest question delivery in Geology 100: General Geology, a non-science major introductory Earth Science course at Washington and Lee University. Funding will support an assessment of the effectiveness of SRT in an environment that is substantially different from most where SRT has previously been utilized. The key objective of this work will be to assess whether SRT Conceptest questioning helps non-science majors; 1) master and retain basic scientific concepts and principles, 2) distinguish between 'good' and 'bad' science, and 3) understand the importance of science in multiple real-world contexts. To evaluate learning and retention, SRT Conceptest questions will be created and compiled for each of 12 key geoscience focus areas. Each focus area will be presented via one of three methods (think-pair-share with SRT, think-pair-share without SRT, and traditional lecture format) during the course and will be presented via a different method each year after the project period. A standard set of examination questions will be dedicated to each focus area at the end of each year to determine whether a

correlation between focus area presentation method and student comprehension exists. A similar set of focus area questions will be presented to willing students one year after course completion to assess long-term retention. At the termination of the funding period, a comprehensive 'manual' of SRT use will be constructed for dissemination to all interested ACS institutions. This product will include SRT Conceptest questions, suggestions for implementation, assessment protocol, and results of this study.

While many institutions are now utilizing SRT in the classroom, to my knowledge, this is the first attempt to assess whether this technology *actually helps non-science majors understand and appreciate science*. Therefore the project effort is focused on understanding the value of SRT in a course designed for non-science majors in a small liberal arts setting. By focusing on specific focus areas and question categories and employing standardized quantitative assessment techniques the goal will be to determine which areas of science, if any, are enhanced by SRT use. This information will be valuable in designing future iterations of the targeted course as well as other non-science major courses. Finding SRT use to be ineffective would be equally useful.

Goals and Objectives

This proposal requests support for the evaluation and implementation of SRT Conceptest pedagogy in an introductory non-science major geoscience course at Washington and Lee and the assessment of the impact of these methods on non-science major learning in the small liberal arts environment. The primary goals of the project are to determine whether SRT has real (not perceived) utility in small introductory Earth Science courses, which <u>categories</u> and in what <u>focus areas</u> (see below) SRT Conceptest questioning is most effective, and which user groups benefit most from this technology. The work proposed systematically and quantitatively explores whether SRT Conceptest use helps students learn more effectively than traditional or pedagogically similar but low-technology methods. The resulting data may also generate novel insights into the different learning processes that are operative in small and large university classrooms and with students of different age, gender, or socio-economic backgrounds. It is stressed that the overriding goal of this project is not to incorporate SRT in the classroom, but to *quantitatively assess* whether SRT Conceptest pedagogy truly helps non-science students learn and retain scientific concepts and principles.

Background and Significance

A number of studies have shown that traditional methods for teaching science to non-science majors are limited in effectiveness (Pinet, 1995; Dufresne et al., 1996; Mazur, 1997; DeCaprariis, 1997; Gerace et al., 1999; McManus, D.A., 2002; McConnell et al, 2003). Several newer teaching models stress active student participation, in which students process material via peer discussion, problem solving, and group activities (Angelo and Cross, 1993; Bykerk-Kauffman, 1995; Mazur, 1997; Yuretich et al., 2001). However, even when more progressive teaching methods are employed, it often is difficult to gauge student involvement, interest, and *most important*, level of comprehension.

SRT presents one method for overcoming these barriers to engagement, self-assessment, and effective learning (Dufresne et al., 1996; Mestre et al., 1997; Wenk et al., 1997; Gerace et al., 1999; Greer et al., 2002; McConnell et al., 2002; McConnell et al., 2003; Heaney and Greer, 2003; Greer and Heaney, 2004). SRT systems collect and display student responses to questions posed in class by the instructor. Data are displayed in class allowing immediate quantitative feedback concerning student comprehension. When used with pedagogically effective

Conceptest questions in class (Mazur, 1997; Leonard et al., 1999; McConnell et al., 2003; Greer and Heaney, 2004; McConnell et al., 2006) SRT highlights what students understand and which concepts they are failing to grasp. This feedback allows the teacher to spend less time on material that has been processed in favor of focusing on 'problem areas'. With SRT students can also gauge their own level of comprehension. When combined with think-pair-share pedagogy this may make students who identify themselves as 'non-scientists' feel more comfortable in pressing for more information. *Theoretically,* SRT use in concert with Conceptest questioning helps non-science major students learn more conceptually and effectively.

While SRT has been deemed a successful instrument of active learning in large university-level courses (Dufresne et al., 1996; Mestre et al., 1997; Gerace et al., 1999; Greer and Heaney, 2004; McConnell et al., 2006), integration of this technology in a small liberal arts curricula has been rare, and this pedagogical method is relatively new in the geosciences. The portability of SRT and Conceptest questioning to small classrooms or liberal arts environments is often vehemently debated. A common assumption is that a small liberal arts classroom fosters such open communication and instructor-student interaction that SRT would in fact be detrimental to student engagement and learning. Yet small liberal arts students who identify themselves as a 'non-scientist' or admit to a fear of science are not necessarily significantly more likely to speak in class, or ask for clarification than similar students in a large university setting.

In order to explore this assumption, the PI conducted a pilot study of SRT use in her Historical Geology course (Geology 102) at Washington and Lee in Winter 2004. A student survey identical to the one used at Penn State (Greer and Heaney, 2004) was given to students at mid semester. Survey results indicate students at Washington and Lee consider SRT to be a highly useful tool for synthesis of course material. In fact, survey responses were more strongly positive than at Penn State in most categories. A significantly higher percentage of Washington and Lee respondents more strongly agreed with the following statements: (SRT) reinforces important concepts presented in lecture, (SRT) improves my problem solving skills, and (SRT) is an effective teaching and learning tool. Perhaps most surprising, despite the small (22 student) class size, a higher percentage of Washington and Lee students agreed that SRT increased their willingness to ask questions in class and 100% of W&L respondents recommend the use of SRT in other classes at Washington and Lee.

The data above only confirm that students *believe* this technology helps them learn! There is no proof to date that SRT Conceptest pedagogy actually improves student retention or understanding of scientific concepts and principles. Therefore there is currently no data to support the idea that this technology better equips our non-science majors to evaluate and assess scientific issues in politics, business, and social concerns once they leave the university setting. This highlights the central purpose of this proposal. If we are to rely on SRT to improve our delivery of science to non-scientists, we must evaluate the true, and not perceived, value of this method. If we can identify specific areas in which SRT Conceptest use is valuable, we can reform our science courses in a meaningful way. This proposal outlines a plan to evaluate student retention and comprehension of geological and general science concepts both with and without SRT use in an academic setting that is distinctly different from those where SRT is more commonly used.

Detailed Project Plan

Approximately 12 specific <u>focus areas</u> critical to course curricula will be identified by the PI in Fall 2006. Focus areas will highlight a particular concept-driven aspect of the geosciences.

It will be a goal of this exercise to identify concepts within each focus area that can be broadly applied to larger scientific principles or other scientific disciplines. Examples of 3 proposed focus areas are highlighted below.

Focus Area 1: Plate Tectonics. This focus area encompasses how and why lithospheric plates move, why plates exist, and the basic principles of convection, conservation of mass, and effects of heat energy on various solid and liquid materials.

Focus Area 2: Earthquakes and Seismicity. Given information about how seismic waves travel, students may calculate the origin of earthquakes, interpret historical earthquake frequency data, or determine whether earthquake prediction is feasible based on what they learn about geophysical data collection methods.

Focus Area 3: Climate Change. This focus area is ideal for exploring the interrelationships between chemistry, physics, biology, and geology. Students may be asked to evaluate feedbacks between components of the earth system, interpret and assess real climate data, or predict future climate scenarios based on material presented in class.

At least 4 SRT Conceptest questions will be developed for each focus area. Conceptest questions (with and without SRT use) will be based on conceptual principles, data analysis, image interpretation, quantitative or qualitative reasoning. Questions will be broadly classified in the following categories: quantitative problems, popular misconceptions of science, applied reasoning, and creative thinking.

In each of the three years of the project period, each focus area will be explored using one of the following three methods:

- Conceptest questions will be presented with think-pair-share methods without SRT
- Conceptest questions will be presented with think-pair-share methods with SRT
- The focus area will be presented without Conceptests, think-pair-share methods, or SRT

In each year of SRT use (during and after the requested funding period) all focus areas will be covered but the subset of the focus areas presented by each of the above methods will change. However a consistent set of questions (representing all focus areas and question categories) will be identified and given at the end each course. Most of these questions will not be asked in a multiple choice format in order to fully evaluate the depth of student understanding of focus area material and the ability of students to articulate scientific ideas. The results of these questions will be compared at the termination of the three year period to examine whether presentation methods correlate with retention or comprehension of the focus area subject matter. One year after completion of Geology 100 a similar set of questions will be given to willing former students to assess longer-term retention of focus area concepts.

Prior Activities

The PI of this proposal has experience with SRT use in the large classroom and large university setting and has experimented with SRT use at Washington and Lee. The PI has presented at national meetings (Greer et al., 2002; Heaney and Greer, 2003; Greer and Heaney, 2004; Heaney and Greer, 2004) and published (Greer and Heaney, 2004; McConnell et al., 2006) on the subject of SRT use. However, the project proposed here is distinctly different from all past endeavors. Initial questions were not primarily concept driven, the former classroom and student body was entirely different from the current academic setting, and *no effort was made to assess whether this technology actually helped non-majors learn and retain scientific principles.*

Projected Timetable

While this proposal only requests funding for the one year in support of this research, the PI is committed to continuing this work for two additional non-supported years if adequate funds are provided by ACS for the first year.

Year 1 (supported by ACS grant):

Summer and Fall 2006

- Development and refinement of assessment protocol and format
- Identification of all focus areas and question categories
- Compilation/creation of Conceptest questions for each focus area and question category (to clarify: this has <u>not</u> been done by the PI during prior experimentation with SRT)
- Development of 3 year map of focus area delivery by presentation method
- Consultation with SRT users from diverse academic environments

Spring 2007

- Integration of SRT technology in Geology 100 at Washington and Lee University
- Compilation and detailed analysis of all SRT data gathered during the course (including correlation of correct and incorrect responses by student profile)
- Internal assessment of student perception of SRT (as outlined in Greer and Heaney, 2004)
- Evaluation by, and collaboration with fellow ACS faculty member Kathleen Surpless (Trinity University) who will visit Washington and Lee
- Development and implementation of end of term standardized examination of all focus areas and question categories (to be applied in all subsequent years)
- Compilation of SRT 'manual' for distribution and dissemination of initial results
- Preparation of presentation of initial results (for Geological Society of America Meeting)

Year 2 and Year 3 (not supported by ACS grant):

- Continued use and evaluation of SRT use in Geology 100 with rotation of methods for instruction in all focus areas
- Presentation of project results and methods (including demo of pedagogical methods) to Washington and Lee faculty and local high school teachers interested in SRT use
- Sharing of SRT response data with Surpless and other interested ACS faculty
- A voluntary post course exam covering all focus areas will be sent to all willing Geology 100 students from each previous year
- Publication and presentation of final results

Requested Budget

Greer salary	\$5000	
Greer travel costs	\$700	airfare (\$300), meals (\$100), lodging (\$300) for 3 days
Surpless stipend	\$600	
Surpless travel expenses	\$700	airfare (\$300), meals (\$100), lodging (\$300) for 3 days
Undergraduate stipend	\$3000	

Institutional support All hardware and software for the Classroom Performance System including upgrades, maintenance, and misc. modifications to the receiving system in the classroom. Washington and Lee will also fully support travel to any regional or local meetings to present results of this work as well as matching funds for Greer to visit ACS and non-ACS institutions currently utilizing and assessing SRT.

Requested salary for Greer is justified as she will consider this a major focus of her semester and summer work as well as work that will continue for an additional 2 non-funded years. The non-funded portion of this work will include the implementation of standardized examination of concept retention of student volunteers 1 year after course completion. Greer will also compile and disseminate a manual of SRT use that includes Conceptest questions for export to all interested ACS institutions. In addition, Greer will supervise an undergraduate student for 10 weeks during summer 2007. The effort and tasks associated with the proposal are not in incorporating SRT technology, but in extensive data analysis, and designing, implementing, and assessing whether this technology helps non-science majors understand and retain scientific concepts, and appreciate the value of science in everyday life.

Requested domestic travel includes funding for Greer to visit Surpless (Trinity University) and other appropriate colleagues to observe current SRT use, associated pedagogy, and assessment protocol. Washington and Lee will match the requested funds for Greer to allow further travel. Requested funding will also support a visit to Washington and Lee by Surpless in Spring 2007. Surpless is currently using SRT in her classroom. The primary purpose of her visit will be to evaluate the merits and methods of assessment protocol and to compare methods for SRT and Conceptest use in the classroom.

An undergraduate stipend is requested for one undergraduate student at $3000 for a summer research stipend in accordance with internal stipends at Washington and Lee. Undergraduate support could result in an internship and/or senior thesis project for a major or non-major student. I will likely seek a student interested in K-12 education as a career path. The student will be involved in data compilation, analysis, and presentation of results.

Course Context

Undergraduate students rarely enroll in introductory Earth Science courses with the intention of becoming professional geoscientists. Often such courses are viewed as the path of least resistance towards satisfying a university's general education requirement. Most students in Geology 100 perceive themselves as unlikely scientists by ability or desire. Many feel incapable of understanding or participating in scientific inquiry and have vague (or misguided) notions of what 'science' is. Geology 100 is an introductory lab science course that serves as a general education core lab science requirement for Washington and Lee students (one of ~10 GE5a choices). While class size is limited to 19, our department teaches 5 (usually full) sections per academic year. Most students major in business, politics, journalism, or are interested in K-12 education. These are all areas in which knowledge of basic science is increasingly critical (and some would argue critically lacking).

Evaluation, Dissemination, and Continued Support

Evaluation, dissemination, and results of the study as well as the continuance of the project after ACS funding are integral to the project and have been discussed above. Individual SRT responses and examination results will also be examined in light of gender, matriculation, and class size. In addition to sharing results with ACS members, results will likely be presented at national geological meetings and published in appropriate journals.

Literature Cited

Angelo, T.A. and Cross, K.P., 1993, Classroom assessment techniques: A handbook for college teachers, 2nd Edition. Jossey-Bass.

Bykerk-Kauffman, A., 1995, Using cooperative learning in college geology classes. The Journal of Geoscience Education, 43, p. 309-316.

DeCaprariis, P.P., 1997, Impediments to providing scientific literacy to students in introductory survey courses. The Journal of Geoscience Education, 45, p. 207-210.

Dufresne, R.J., Gerace, W.J., Leonard, W.J., Mestre, J.P., and Wenk, L., 1996, Classtalk: A classroom communication system for active learning. Journal of Computing in Higher Education, 7, p. 3-47.

Gerace, W.J., Dufresne, R.J., and Leonard, W.J., 1999, Using technology to implement active learning in large classes. University of Massachusetts Physics Education Research Group Technical Report PERG-1999#11-Nov#2, 22 p.

Greer, L. and Heaney, P.J., 2004, Real-time analysis of student comprehension: An assessment of electronic student response technology in an introductory Earth Science course. Journal of Geoscience Education, 52, p.345-351.

Greer, L., Heaney, P., and Houseman, D., 2002, Mutual assessment: understanding faculty teaching and student learning via electronic student response technology. Geological Society of America Abstracts with Programs. *Invited Speaker.*

Heaney, P.J. and Greer, L., 2003, Using electronic response technology to teach mineralogy in large class settings. Clay Minerals Society Program and Abstracts, p. 73.

Heaney, P., and Greer, L., 2004, Assessing the effectiveness of electronic student response technology. Geological Society of America Abstracts with Programs, v. 36, no. 5, p. 490.

Leonard, W.J., Gerace, W.J., and Dufresne, R.J., 1999, Concept-based problem solving: Making concepts the language of physics. University of Massachusetts Physics Education Research Group Technical Report PERG-1999#12-NOV#3, 18 pp.

Mazur, E., 1997, Peer Instruction: A User's Manual. Prentice Hall, 253 p.

McConnell, D., Steer, D., and Owens, K., 2002, Conceptests and a personal response system: Using technology to enhance inquiry-based learning in an introductory geology course. Geological Society of America Abstracts with Programs.

McConnell, D., Steer, D., and Owens, K., 2003, Assessment and active learning strategies for introductory geology courses. Journal of Geoscience Education, 51, p. 205-216.

McConnell, D.A., Steer, D.N., Owens, K.D., Knott, J.R., Van Horn, S., Borowski, W., Dick, J., Foos, A., Malone, M., McGraw, H., Greer, L., Heaney, P.J., 2006, Using Conceptests to assess and improve student conceptual understanding in introductory Geoscience courses, Journal of Geoscience Education, 54, p. 61-68.

McManus, D.A., 2002, The two paradigms of education and peer review of teaching. Journal of Geoscience Education, 49, p. 423-434.

Mestre, J.P., Gerace, W.J., Dufresne, R.J., and Leonard, W.J., 1997, Promoting active learning in large classes using a classroom communication system. In: The changing role of physics departments in modern universities: Proceedings of International Conference on Undergraduates Education (Redish and Rigden, eds.). American Institute of Physics, p. 1019-1021.

Pinet, P.R., 1995, Rediscovering geological principles by collaborative learning. the Journal of Geoscience Education, 43, p. 371-376.

Wenk, L., Dufresne, R., Gerace, W., Leonard, W., and Mestre, J., 1997, Technology-assisted active learning in large lectures. In: Student active science: Models of innovation in college teaching, A.P. McNeal and C. D'Avango (eds.), Fort Worth, TX, Saunders College Publishing, p. 431-451.

Yuretich, R.F., Khan, S.A., Leckie, R.M., and Clement, J.J., 2001, Active-learning methods to improve student performance and scientific interest in a large introductory oceanography course. Journal of Geoscience Education, 49, p. 11-19.

Disclosure Statement

The PI has no other on-going or submitted grant proposals at this time.

Curriculum Vitae for Lisa Greer

Assistant Professor, Geology Department
Washington and Lee University
Lexington, VA 24450 (540) 458-8870 (office) greerl@wlu.edu

Professional Preparation

B.A.	May, 1993	Advisors: Paul Myrow and Al Curran (Smith College)
	The Colorado College, *Geology*	
Ph.D.	December, 2001	Primary Advisor: Peter K. Swart
	University of Miami-Rosenstiel School, *Marine Geology (Geochemistry)*	

Professional Appointments

2003-present	Assistant Professor, Washington and Lee University, Geology Department
2001-2003	Assistant Professor, Penn State University, Department of Geosciences
2000	Adjunct Faculty, Florida International University, Department of Geology
1998	Teaching Assistant, The Maritime and Science Technology Academy Magnate High School, Department of Math and Science
1996-2000	Consultant Researcher, The Nature Conservancy Latin Amer. and Carib. Division
1995-2001	Research Assistant, University of Miami Rosenstiel School, Marine Geology
1994-1995	Teaching Assistant, University of Miami, Department of Geological Sciences

Recent Publications and Presentations Most Closely Related to this Project

Knapp, E.P., **Greer, L.**, Connors, C.D., and Harbor, D.J., *accepted for publication*, Field-based instruction as part of a balanced Geoscience curriculum at Washington and Lee University. Submitted to Journal of Geoscience Education 2005.

McConnell, D.A., Steer, D.N., Owens, K.D., Borowski, W., Dick, J., Foos, A., Knott, J.R., Konigsberg, A., Malone, M., McGrew, H., Van Horn, S., **Greer, L.**, and Heaney, P.J., *in press*, Using Conceptests to assess and improve student conceptual understanding in introductory Geoscience courses. *Journal of Geoscience Education,* v. 54, p. 61-68.

Greer, L. and Heaney, P.J., 2004, Real-time analysis of student comprehension: An assessment of electronic student response technology in an introductory Earth Science course. *Journal of Geoscience Education,* v. 52, p. 345-351.

Furman, T. and **Greer, L.**, 2004, Active learning in introductory geoscience courses. http://www.pkal.org/docs/intro-geosciences-furman.pdf, published on the web via Project Kaleidoscope, 5 p.

Greer, L. and Heaney, P., 2004, Does electronic student response technology work in a small liberal arts classroom? Geological Society of America Abstracts with Programs, v. 36.

Owens, K., McConnell, D.A., Steer, D., Van Horn, S., Knott, J., Borowski, W., McGrew, H., Dick, J., Greer, L., and Malone, M., 2004, The impact of changing pedagogy to include conceptests and peer instruction in introductory geoscience courses at multiple institutions. Geological Society of America Abstracts with Programs, v. 36.

Additional Publications

Greer, L. and Swart, P.K., *accepted for publication*, Decadal cyclicity of regional Mid-Holocene precipitation as driven by tropical Atlantic sea surface temperatures: Evidence from Dominican coral proxies. Submitted to Paleoceanography, 2005.

Guerard, G. M., **Greer, L.**, and Curran, H. A., 2004, Environmental indicator proxies from a mid-Holocene coral reef, Enriquillo Valley, Dominican Republic. Proceedings of the 11th Symposium on the Geology of the Bahamas and Other Carbonate Regions, p. 35-48.

Swart, P.K., Price, R.M. and **Greer, L.**, 2001, The relationship between stable isotopic variations (O, H, and C) and salinity in waters and corals from environments in South Florida: Implications for reading the paleoenvironmental record. *Bulletins of American Paleontology*, vol. 361, p.17-30.

Swart, P.K., Healy, G., **Greer, L.**, Lutz, M., Saied, A., Anderegg, D., Dodge, R.E., and Rudnick, D., 1999, The use of proxy chemical records in coral skeletons to ascertain past environmental conditions in Florida Bay. *Estuaries*, vol. 22, No. 2B, p. 384-397.

Synergistic Activities

2004 Co-chair of topical session titled, *Electronic Student Response Technology in the Geoscience Classroom: Is it a Valuable Teaching and Learning Tool?* at GSA annual meeting in Denver, 2004. Twelve presentations were given and followed by a highly attended and very informative group discussion on the pros and cons of this technology.

2003 Served on development and search committee for new Geoscience Educator faculty position, Department of Geosciences, Penn State University, University Park.

2002 Lead presenter and facilitator of *Creating an Interactive Classroom using Electronic Student Response Systems*, at Assessment Strategies to Stimulate Student Learning Colloquy, Penn State University. Featured article in the Penn State Intercom Newspaper (*Assessing student learning*) in section: Celebrating Teaching and Learning.

2001 Facilitator and participant of *Designing a Learner-Centered General Education Course*, at Expanding Student Centered Learning Colloquy, Penn State University.

to date Co-author with undergraduate students on 22 published abstracts from national meetings and papers in press (*Washington and Lee University, Smith College, Franklin and Marshall, Mary Washington University, Oberlin College, Amherst College, Cornell College, Penn State University, University of Chicago*)

Relevant Honors, Awards, Scholarships and Grants

2005 Keck Proposal: 2005, The rise and demise of a Holocene coral reef complex, Dominican Republic: The coral-climate connection. Keck Geology Consortium, Funded

2002 Wilson Education Grant, Penn State University

2002 Center for Excellence in Learning and Teaching Grant, Penn State University

2002 Summer Salary Grant (2 months) for research in teaching and learning, Penn State

2001 Center for Excellence in Learning and Teaching Grant, Penn State University