Peer Review for the Digital Earth: A Journal of Earth System Science Education

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ABSTRACT: Within Earth system science, the Earth is viewed as a synergistic interrelated physical system of phenomena and processes embracing many disciplines. Earth system science is now widely regarded to be the valid framework from which to offer interdisciplinary courses concerning the relationship between the Earth and humankind. Colleges and universities are developing Earth system science educational resources for the classroom and laboratory. These content-rich resources range from the simplicity of an annotated set of satellite images through the multi-week topical learning module to the complexity of a complete course, and can be valuable for educators everywhere. A digital Earth promises new tools for easier access to data by Earth system science educators. An organized web-based repository of Earth system science and digital Earth education learning resources is needed, with provision for peer review to ensure quality classroom materials and academic reward for authors and developers. A peer reviewed online Journal of Earth System Science Education (JESSE) is being established for the purpose of creating a common repository of quality Earth system science and digital Earth education resources for undergraduate and graduate classroom instruction. Equally as important, JESSE peer review will offer to the authors of these materials the recognition deserved for their commitment to education. JESSE will draw upon the experience of established networks of institutions to define review criteria, and will work in close coordination with other geoscience digital library and digital Earth projects. Copyright of all materials contributed to JESSE will remain with the author.
KEY WORDS digital Earth, Earth system science, peer review, electronic journal, education

1. Earth System Science

Earth system science views the Earth as a synergistic physical system of interrelated phenomena, governed by complex processes and relationships. Fundamental to the Earth system science approach is the need to emphasize relevant interactions of chemical, physical, biological and dynamical processes that extend over spatial scales from microns to AUs (astronomical units), and over time scales of milliseconds to billions of years. The system approach to the study of the Earth, which builds upon traditional disciplines, has become widely accepted as the valid framework from which to pose disciplinary and interdisciplinary questions in relationship to humankind. Earth system science forms the foundation of NASA's Earth science vision as well as the basis of the NSF geoscience long range planning effort as part of the United States' global change research objectives.

The concept of the Earth as a complex and dynamic entity of interrelated phenomena involving the geosphere, atmosphere, hydrosphere and biosphere is most evident. There is no process or phenomenon within the Earth system that occurs in complete isolation from other elements of the system. While this system view is elegant and satisfying philosophically, the challenge to researchers and educators attempting to quantify the breadth of the system's elements, states and processes within the classroom is enormous. No individual, academic department or university is capable of developing and offering the enormous depth and breadth of knowledge such a paradigm demands. Only by joining faculty from different disciplines within and among universities can the diversity and complexity of Earth system science be fully appreciated.

The challenge for educators to develop and offer courses in the classroom that provide this deeper understanding is demanding. Earth system science seeks to construct an overarching interdisciplinary framework of process and state of the system, and at the same time retain the strength of traditional disciplines for understanding fundamentals and complex interactions. Colleges and universities have been attracted by this holistic approach to studying the Earth and adopt Earth system science as a theme. In developing and offering introductory and advanced courses which are relevant to the broader interests of faculty and students, the challenge is to provide the necessary depth and breadth needed to serve as a foundation for advanced study among majors, and lay the foundations for sustainability and informed stewardship in striving for an Earth-aware society.

Earth system science in the classroom is being developed through programs such as the ongoing NASA/USRA Cooperative University-based Prog-

ram for Earth System Science Education (ESSE). The universities involved in ESSE adopt Earth system science as a theme for both lower and upper level undergraduate course offerings, while a few aim to develop departments or schools of Earth systems (Johnson *et al,* 1997). Colleges and universities develop Earth system science educational resources for the classroom and laboratory, teaching about the Earth as a system. These content-rich resources range from the simplicity of an annotated set of satellite images through the multi-week topical learning module to the complexity of a complete course, and can be valuable resources for educators everywhere. An organized web-based repository of Earth system science education learning resources is needed, with provision for peer review to ensure quality classroom resources and academic reward for authors and developers.

The ESSE Program maintains such a web-based repository of links to Earth system science education and research information. Earth System Science *Online* (http://www.usra.edu/esse/essonline) organizes interdisciplinary educational materials for easier access by instructors and students aiming to be a resource for ESS educators looking for science links, learning modules, program opportunities, partner contacts, news updates and other information relevant to Earth studies. The biological and social sciences also need to be represented in the Earth system, as well as the human dimensions of sustainability and economics. ESS *Online* offers an eclectic collection of relevant interdisciplinary resources and links focused on the needs of Earth system science educators.

2. Digital Earth and Earth System Science

The vision of a Digital Earth presented by Gore and others has enormous consequences for Earth system science (ESS) educators at all levels (Gore, 1998). Providing geo-referenced spatial and temporal data directly to students will connect global and local processes and phenomena in ways not possible only a few years ago. The possibilities for communication and learning are endless. However, data and information by themselves need a context and learning framework in order to be effective learning tools. An image of a hurricane from space is impressive, and can be used as a "throw away" to capture attention. But information added to and available with that image about scale, process, state and dynamics forms the basis of a "learning object", a reusable learning resource that can be used to help understand weather, climate, atmospheric physics, thermodynamics, hydrology, geography, social processes and many other topics. Learning objects combine raw data, imagery, text, graphics, animations, etc. with documenting reference and supporting information. By combining several of these learning objects, educational developers can construct learning modules, which in turn can be joined to prepare courses, lectures or laboratory exercises which are tailor made to meet the instructional needs of an educator. In order for the Digital Earth to be a compelling resource for educators, its content must be incorporated into the learning environment in the context of learning objects, modules or courses which foster guided inquiry and exploration into the Earth system using best pedagogical practices.

The Digital Earth has a large potential audience, from the general public to policy makers, from students of all ages to managers. The common thread for all users is a desire or need to learn: to learn about the weather for today's game, to learn about the demographic trends in the use of a resource, to learn about long term impacts of a land use policy or to learn about the recreational opportunities at a vacation spot. A primary goal for the Digital Earth is to educate its users about some aspect of the planet or its population, using geospatial data sets as a reference, coupled with advanced navigational aids and visualization tools. The navigation and visualization tools used by learners must point to primary content learning objects such as tutorials, background information, references, etc. for the Digital Earth to achieve its full potential.

This potential can be achieved with a modular Earth system approach which assembles a set of discrete yet related learning objects in a guided learning context. Modules are a practical solution for instructors seeking to incorporate Earth system science content in their classrooms. Individual resources, some as simple as an annotated image, can be combined to form thematic modules, or used alone as supplements to existing course materials. An instructor can assemble an entire course using a customized set of modules, or supplement an existing course with selected modules and learning objects.

3. Modules in Knowledge Space

Consider "knowledge space", an n-dimensional infinite volume whose axes could be loosely defined as disciplinary understanding, where distance along an axis relates to depth of knowledge. Learners typically hover about the origin as they begin their journey through this space, gaining general knowledge in a variety of areas. As learning progresses, a set of generally linear paths along

disciplinary vectors is followed, leaving much of the interdisciplinary space un-traversed. The learner's goal is to apply the knowledge gained along the paths taken to achieve some level of proficiency (e.g. grade school, high school, college, postgraduate, etc.) in dealing with the "real world" (also know as the Earth system), which indeed fills interdisciplinary knowledge space. New pathways through this Earth system science knowledge space can be defined through the use of learning modules demanding knowledge from several disciplines.

Interdisciplinary modules bridging the voids in knowledge space provide unusually rich learning opportunities for the classroom. The modules usually draw upon disciplinary learning objects to ensure the necessary depth of knowledge in a subject, but also span disciplines ensuring breadth. As interdisciplinary modules are developed which populate the Earth system knowledge space, instructors will be able to choose a path from module to module drawing upon disciplinary learning objects which best meets the needs of the course. A map of multiple paths through interdisciplinary knowledge space can be created, offering guidance and suggestions to instructors for reaching a common destination, drawing upon the strengths of their own background and disciplinary interests. Modules can also be designed which make technically complicated tools (such as modeling, computation, or visualization) easy to customize or modify by other educators, thereby creating a "new" learning object.

Modular content is also digestible. Online courses, outlines and syllabi developed by others can be very useful when attempting to initiate Earth system science education programs, but there is also the need for more portable and concise learning objects that can be assembled into a custom course or used to augment an existing course. Most instructors are unable to assimilate entire courses or even large blocks of material into their classrooms. More often an instructor desires to create a specialized set of lectures and labs that build upon the instructor's own unique interests and abilities, and meet the institution's and students' needs for a specialized learning experience that is integrated into the fabric of the curriculum. A course dealing with local and regional issues relating to global change is an example.

The ESSE program participants have been formally and informally developing modular content (Kalb *et al*, 1997) and continue to share their materials via the Internet. The community also recognizes that the modules should be organized and made available with some common features to make them easier to link to each other and to incorporate into existing learning environments. Module content, pedagogy and presentation style should also be reviewed to promote high quality learning materials.

4. An Electronic Journal of Earth System cience

The concept for a peer reviewed Journal of Earth System Science Education (JESSE) stems from discussions and recommendations made during a series of workshops and working group meetings conducted as part of the ESSE program since 1994. The groups recognized the need for an orderly repository of resources, and the value of peer review to the educational user as well as the author.

A prototype version of JESSE is being developed for the purpose of creating a common repository of quality Earth system science education resources for undergraduate and graduate classroom instruction. This effort aims to establish a pathfinder proof of concept Journal with limited holdings in this phase of the project, and seeks to define a working structure and process for peer review and operation of the Journal on a limited scale. Equally as important, JESSE peer review will offer to the authors of these materials the recognition deserved for their commitment to education, and may assist in institutional reward and tenure decisions.

At the heart of JESSE is the peer review process. The Internet empowers new means for efficient and thorough peer review. JESSE will implement an innovative and open peer review process, encouraging reviewer-developer communication and open-record reviews and comments, including reviewer attribution. When the need exists, provision will be made for confidentiality during beta testing.

To assist with the process, and to seek interdisciplinary ESS community support, an Editorial Board consisting of Principal Editors and Co-Editors has been established. Board members, as Co-Editors, act as advisors to Principal Editors, and will assist with the definition of the review process and designation of reviewers. JESSE will draw upon the experience of the ongoing ESSE network of institutions, and will work in close coordination with the NSF-funded Geoscience Digital Library (GDL) (Marlino *et al*, 1999). JESSE will also work closely with the Columbia University Press *Columbia Earthscape* project, a developing interactive library resource on the global environment (Haber, 1999).

Unlike traditional paper publication, JESSE will be reviewing contributed materials which in many cases are already being made available via the Internet. JESSE will add value to these resources

by conducting a peer review of their content, pedagogy and presentation format. Upon acceptance of the resource, publication on the JESSE web site or at a digital library becomes a permanent record and recognition of the author's work.

JESSE will review and publish only those resources that have been submitted to the Journal by the developing author(s). Contributions may be solicited or unsolicited. JESSE, or it's partners within the ESSE, *Columbia Earthscape* or GDL programs, may solicit authors directly to contribute specific materials to JESSE that are already in use or being distributed on the Internet. As the Journal matures the number of unsolicited contributions directly from authors is expected to increase.

For the purpose of this pathfinder proof of concept, JESSE will focus on reviewing and publishing undergraduate level education materials that are designed to be freely available on the Internet. Copyright of all materials submitted to JESSE will remain with the authors, with the understanding that the materials will be archived and openly available through the JESSE server or affiliated digital library. JESSE will organize and *link* to resources (as identified by the editors, the editorial board, ESSE, *Columbia Earthscape* or GDL) which have the potential to make a contribution to ESS education. This larger group of links forms a repository of *community* resources – educational resources which are not yet reviewed or published by JESSE, but which are considered to be useful for the ESS education community.

Community resources that are submitted for review by JESSE become *beta* resources. Beta resources are cataloged in the JESSE database along with ancillary information about the authors, subject area, learning level etc. Beta resource metadata structure and format will be consistent with the IMS metadata standards for learning objects recently released (Wason *et al*, 1999). Resources passing through peer review will be published and archived on the JESSE server under configuration control (i.e. change protection). Ancillary resource metadata will be expanded to include review comments, change history, notes from classroom experiences, suggestions for future use, etc.

Educational resources for Earth system science are by nature diverse in their scope, content, presentation format and pedagogical style. JESSE will develop a process and structure to address a diversity of interests during peer review and publication, and organize content to meet the needs of the educator/user. JESSE will also develop learning object categories based upon the scope of the materials submitted. The proposed categories are:

1) Short notes – learning objects designed to enhance a lecture or laboratory with specific information or a focused exercise. An example would be a collection of annotated images of cloud types or volcanoes or coastal erosion.

2) Modules – learning objects which address a particular topic in some depth and are designed to lead or augment several hours of lecture, lab or student exploration. Examples include on-line and CD-ROM based learning exercises or the guided use of a collection of shorter resources.

3) Extended resources – learning objects which are designed to be the primary focus of a course or unit, spanning at least several weeks of classroom, laboratory or student time. Examples include an online course or textbook dealing with Earth systems concepts.

4) Other resources such as annotated bibliographies, papers about Earth system science education philosophy, pedagogy, reviews of pedagogical methods for ESS, the use of data to create content, etc.

These categories will be modified and expanded if necessary as JESSE matures. Resources which are primarily intended to distribute data, or to manipulate data (e.g. satellite data archives, census information, map servers, etc.) can be valuable for educators due to the primary content they serve and may be listed with commentary concerning utility. However, such resources will not be considered for review by JESSE. Learning objects which take primary data and use it as part of a guided learning exercise for the classroom will be considered.

ESS education resources will be used in the classroom and laboratory as part of courses and as supplements to textbooks. In addition to linking to community and published ESS resources, JESSE plans to create a database of ESS courses being offered at post-secondary institutions, collecting information such as institution, department, course title, instructor, class size, syllabus, textbook used, learning resources used, etc. This online database will enable JESSE users to review other approaches to teaching ESS, and draw upon the collective experience of the community. JESSE also plans to create an ESS textbook database, collecting standard title, author and publisher information, and including tables of contents, book reviews and notes from instructors on how the book is being used. Each of these databases will be searchable on-line via the web.

JESSE will be updated on a continuing basis with new beta resources posted as they become

available, and resources published as reviews are completed. As such, the journal has no fixed publication dates. For the purposes of review however, orderly timelines will be established to assure timely publication of submittals.

The establishment of JESSE as a common review mechanism for ESS resources is timely in view of the emergence of ESSE module development efforts, *Columbia Earthscape* and GDL. JESSE also addresses recommendations laid out in *Shaping the Future of Undergraduate Geoscience Education* (Ireton *et al*, 1996) and *Geoscience Education: A Recommended Strategy* (Somerville, 1997). In early August, 1999, NSF and NASA sponsored a workshop to produce a community vision for the Digital Library for Earth System Education and an action plan for building the library (Johnson *et al*, 1999). The working groups recognized the need for a core collection of rigorously peer reviewed learning materials (Manduca *et al*, 1999), further validating the need for JESSE.

The result of this JESSE pathfinder effort will be the development and refinement of a community-based peer review process for electronic Earth system science education resources; the concurrent establishment of an academic reward mechanism for resource authors and developers of peer-reviewed publications; and the creation of a web-based repository of quality resources for educators in association with the ESSE Program, the Geoscience Digital Library and *Columbia Earthscape.* The JESSE web site is http://www.usra.edu/esse/jesse.

5. Summary

Earth system science has come of age in the 1990s and should be embraced in the new millennium as one of the founding principles for the implementation of the Digital Earth. Earth system science can provide the knowledge space frame-work within which disciplinary and interdisciplinary content material can be developed in a modular format to meet the needs of educators and students at all levels. The innovative visualization and navigation technologies for geospatial data being developed within the Digital Earth must be able to link to substantive explanatory content at appropriate learning levels. This content is best developed by classroom educators and researchers who know the needs of their students and share the results of their work. Modular learning objects developed by the community will be shared on the Internet and made available through repositories such as the NASA / NSF Digital Library of Earth Systems Education, currently under development. To assure quality of content and pedagogical effectiveness, learning materials should be reviewed and published by organizations such as the Journal of Earth System Science Education, which also serve to reward authors and developers with peer reviewed publication records.

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