GIS by Design

Bob Coulter

Abstract: In an era of crowded curriculum mandates and high-stakes testing requirements, simply fitting GIS in becomes a herculean task. Many classroom teachers work valiantly to integrate GIS into their curriculum, and teacher-educators have evangelized in support of GIS as the solution to a variety of educational challenges. Despite this fervent effort, meaningful GIS applications in the K-12 classroom remain uncommon. In an effort to address these concerns, teacher education programs at the Missouri Botanical Garden have adapted the highly successful Understanding by Design curriculum planning model to support a range of GIS-based teacher institutes. In this session, the evolution of the model and its documented success in changing teacher beliefs and practice will provide the basis for a review of the institute structure and the planning templates used.

The history of educational technology is populated with a seemingly endless sequence of fads, one following on the heels of its predecessor, each claiming to be the best solution to our educational ailments. Like New England weather, if you wait a short time conditions change and a new fad is upon us. Previously (Coulter, 2004) I have argued that GIS is likely to join this parade of educational panaceas if we do not pay greater attention to the educational context into which we seek to integrate the software. Summarizing the earlier work, I argued that we need to create learning environments in which the need for geospatial tools is obvious, rather than look for ways to infuse GIS into the curriculum. If we can do this, the software tools have a solid chance of becoming an integral part of the teaching and learning environment; if not, GIS is destined to be short-lived on the educational landscape, or relegated to a backwater. More broadly, if geospatial analysis truly has the transformative power we believe it does, our failure to make it an integral part of the teaching and learning environment is ultimately a loss for teachers and students.

Continuing that argument, the effort here is to describe the power of a curriculum design process used at the Missouri Botanical Garden that has achieved documented results in increasing teacher use of geospatial analysis in the classroom (Polman and Coulter, 2004). The core of this effort has been the use of elements derived from the Understanding by Design curriculum model (Wiggins and McTighe, 2005) as the basis for teacher professional development workshops. Owing in large part to the more deliberate planning for implementation (and the likely increase in "buy-in" from teachers that goes with this effort), use of GIS went from 50% to 80% in the first year in which the model was used as the intellectual core of the workshops. Previously, efforts were directed primarily at GIS software training and increasing the academic content background of the participating teachers. Building on this success, new resources (e.g. Wiske, 2005) that extend this curricular focus on "understanding" to the opportunities and challenges afforded by technology-rich environments are being implemented this summer as additional resources to better position geospatial technologies for a significant role in K-12 classrooms.

What is Understanding by Design?

The Understanding by Design model developed by Grant Wiggins, Jay McTighe, and others attempts to focus the attention of teachers more on the strategic intents and outcomes of their curriculum, and less on the specific activities. Often known as "backwards design" the process starts with defining what students will know or be able to do as a result of engaging in the unit. This is best framed as one or more enduring understandings that have value beyond the specific unit being taught, instead of a collection of factlets that will be soon forgotten after the test. For example, being able to regurgitate the 50 state capitals is of considerably less educative value than being able to describe the historical, cultural, and geographic reasons for why your state capital is located where it is and why it has (or hasn't) moved over time.

Once you as the curriculum designer know what students should understand after engaging in your unit, consideration moves to how you can capture and document this understanding. The limitations of current testing paradigms are deep and pervasive, particularly if we hope to have students reach more intellectually significant enduring understandings. Instead, authentic performances that require students to demonstrate their understanding are much more likely to be productive. This is not to say that you can't test for basic skills; rather, we simply need to be careful that these building blocks aren't allowed to substitute for what it means to be educated. The basic skills by themselves are necessary but not sufficient components of education. Without seeing how students' knowledge and skills are embedded in (and contributing to the growth of) their overall conceptual structures, we cannot know what they truly understand.

Having established what students will be expected to understand, and having a plan for how this understanding will be demonstrated, then (and only then) can meaningful lesson planning take place. Without the reference points provided by the other steps in the process, lessons all too often end up as a hodge-podge of activities. Even if the activities prove to be engaging, there is too great a risk that they will not achieve the significance and coherence they would if they were selected for their relevance in helping students achieve and be able to document their competence relative to the specified enduring understandings.

While these planning elements are not unique to the Understanding by Design (UBD) model, the sequencing and primacy given to enduring understandings as the ultimate outcome measure goes a long way in moving a curriculum toward intellectual significance. The Teaching for Understanding (TfU) program at the Harvard Graduate School of Education (Wiske, 2005), compatible in many ways to the UBD framework, offers a powerful framing of the outcome of this process, suggesting that students who truly understand should have a "flexible performance capability" that includes:

- adequate content knowledge,
- the ability to engage in disciplined reasoning,
- an awareness of the strengths and limitations of different ways of seeing the world
- an ability to use representations that are effective and appropriate to a given purpose.

Within the context of a richer, more substantive inquiry as framed by the Understanding by Design and Teaching for Understanding paradigms, geospatial analysis will often be an integral component of a student's "flexible performance capability." Given the capacity of maps to augment other representations of knowledge, GIS can make a substantial contribution to achieving each of the four components listed above. Certainly maps can support increased content knowledge and geospatial reasoning under the guidance of a skilled teacher. At a more "meta-level" of consideration, students can be led to a greater understanding of when geospatial analysis, quantitative analysis, or other methods may be most appropriate and productive. Finally, within the context of an authentic performance, the creation and explanation of the thinking behind maps and graphs created by a student will go a long way toward supporting growth in students' capacity to use representations effectively.

Using GIS as a Modeling Tool

As important as GIS can be as part of the educational landscape, it may be educationally productive to reposition it as one of several modeling tools useful in helping students to investigate environmental or social phenomena. Often, the abstract nature of concepts such as prey/predator relationships and the impact of abiotic conditions (such as temperature and precipitation) on the biotic or living components of an ecosystem will either confuse students or lead to oversimplification. Instead, a modeling approach that creates effective representations of these abstract relationships provides a powerful set of tools which teachers and students can use to think about environmental issues. Ideally, this would include maps, graphs, and first-hand experience with related phenomena.

For example, a common environmental education activity has students act out links along the lines of "who eats whom" in an ecosystem. Some curriculum guides (e.g. Hogan, 1994) even support field investigations of these relationships as students look for evidence of feeding. These approaches by themselves do not rise to the level of enabling students to achieve environmental understanding. Instead, students need to go beyond the activity phase and engage in modeling the population dynamics of predator-prey relationships, including essential abiotic data. A minimal level of environmental *knowledge* encompasses the understanding that a northern lynx preys on snowshoe hares. More complete *understanding* requires an ability to model (spatially) the interrelationship of their respective ranges and (quantitatively) population estimates over time, including representations of the impacts of annual weather fluctuations.

While the complexities of these relationships will need to be modulated to suit the developmental level of the students, research has proven that students can work with complex data and often find this engagement with real problems to be more engaging than traditional learning (National Science Foundation, 2004). Students who are so motivated, who interact with a phenomenon experientially, and model it geospatially and quantitatively are much more likely to achieve the flexible performance capability that is indicative of true understanding. To use a table metaphor, each of these components (or legs) supports the stability of the overall conceptual structure better than could happen in the absence of one of the legs.

Given the importance and potential benefits of framing GIS use within a modeling approach to education, designing for effective implementation becomes the paramount concern. Lehrer and Schauble (2003) identify specific factors that are required in a productive modeling environment. Most fundamentally, they argue that students engaged in authentic modeling need to go beyond simply using some aspects of the world to represent others. While young children do this routinely in their play (as do older children in video games, for example), simple substitution is inadequate. Instead, modeling in this context requires a higher level of awareness both of the modeling process and how it helps foster understanding of the scientific principles involved.

Lehrer and Schauble argue that meaningful modeling is based on the representations that are used as conventions within a disciplinary community such as ecologists or climatologists. Use of geospatial data sets produced by professionals provides ample opportunity for teachers and students to engage in discipline-based representations of data. As they do this, the dual process of coming to understand models as generic tools to think with and coming to a better understanding of the specific concepts under investigation is fostered.

As greater sophistication is gained, learners will be able to develop their understanding of how a model is always a selective representation of reality, with some elements highlighted and others muted or removed altogether. Through the interactive mapping capacities contained within a GIS-enhanced investigation, students will be able to adjust the features mapped. Thus, instead of a textbook or web site presentation of “the storm track,” students will be able to model specific elements of the storm. A simplistic map would show the latitude and longitude of the storm center as it changes over time; a more complex and meaningful learning environment (such as is proposed here) enables students to select and represent specific attributes of the storm track. For example, how does the pressure or speed change over time? Is there a correlation between the two? Is there a predictable “contour” for how these variables change over the life of a storm? More generally, this mathematization of the phenomena brings depth to the inquiry as specific attributes are measured and compared, and breadth as students develop the conceptual “handles” that enable comparison of diverse but related phenomena, such as storms in the Atlantic and Pacific regions.

True inquiry begins when students see data as something that can be questioned (Feldman, Konold, and Coulter, 2000). In support of this, geospatial tools equip students to interact with the models, understand their strengths and limitations, and develop the capacity to compare and evaluate how well different models “fit” reality. From comparatively pedestrian concerns such as the daily weather forecast to much larger concerns such as global warming, models are an essential component of understanding. Students who have the opportunity to work interactively with models will be in a much more educated position, ready to read news reports and interpret partisan advocacy with a critical eye.

Planning for Understanding: GIS by Design

If we accept the utility of the largely similar Understanding by Design and Teaching for Understanding frameworks as means of supporting students’ development, and the more general concept of GIS as being one of several useful data modeling tools, teacher professional development must be framed in a different light. The work undertaken by the Missouri Botanical Garden’s Mapping the Environment program for the past two years has been in large part to develop alternative professional development models that go beyond GIS training. In a sense, we need to move past “GIS-centric” teaching and toward instruction focused on promoting understanding, augmented by geospatial and other modeling tools.

Mapping the Environment institutes have evolved to the point that a primary outcome for teachers (in addition to enhanced GIS skills) is a curriculum plan that articulates three key components:

- the overarching understandings that students should gain,
- the ways in which this understanding will be measured, and
- instructional plans – some using GIS – that help students develop understanding

While the specifics of each institute have varied based on the needs and interests of the participants and continuing program development the general template remains the same: Guided consideration of larger curriculum goals, development of a sample unit in common (to the stage of a mock-up), and substantial time for mentored curriculum development and feedback from peers. This curriculum development strand is fully interwoven within the context of the specific institute (e.g. Science of the Lewis and Clark Trail, Mapping Seasonal Change, Mapping Environmental Issues). To facilitate unit planning, an online template provided by the UBD Exchange (www.ubdexchange.org) on a subscription basis was used in 2003 and 2004. This has proven to be useful in scaffolding development of the different elements of a successful unit plan, but it has proven to be somewhat cumbersome, so an alternative planning template will be used beginning with the summer 2005 institutes.

Data on the first two years show that among teachers who complete the program, unit implementation has moved from about 50% in more GIS-focused workshops held previously to about 80% in the more recent understanding-focused workshops. The remaining teachers typically report software installation difficulties and/or schedule constraints as being the primary obstacles. These factors will likely always continue to affect some percentage of workshop participants (as they did in the past), but the reduction in the non-implementation rate from 50% to 20% suggests that the strategic approach has been successful. While the research design for the program doesn't allow definitive analysis, we hypothesize that the greater curriculum alignment and personal commitment fostered through the unit design process increases teachers' motivation to move past the obstacles and toward implementation. GIS becomes part of the learning plan, and not just another tool to be used if time permits (which all too often, it never does). As a side note, virtually all teachers report that their thinking about curriculum and student learning has been deepened through the focused attention on planning for understanding. This in the long run may be the more significant outcome as it puts teachers in a position to be much more strategic in their pedagogy, counteracting the larger trends current in education that seek to de-skill teachers and devalue their professional judgment.

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Author Contact Information

Bob Coulter
Senior Manager – Education Division
Missouri Botanical Garden
PO Box 299
St. Louis, MO 63166-0299
(314) 577-0219
(314) 577-0847 fax
bob.coulter@mobot.org