The Educational Value of GIS for Cognitive Development

By

Harold L. Hayes

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Abstract

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This presentation will demonstrate how GIS software can be used within my teaching model to promote mastery of abstract concepts and relationships in the Earth sciences. These abstractions are not easily mastered and will not develop intuitively through incidental exposure in the classroom. This premise is based upon many years of classroom teaching experience ranging from the primary grades through adult education.

The presentation will accomplish two objectives. First, it will identify and define the structural components of the pedagogical model which range from the psychological features of the model through the Earth science example to the cognitive mastery of the new abstractions. Secondly, the presentation will show how GIS software can be used to integrate the subject matter content and create operational level mastery of that content.

Introduction:

Ever since my first experience with GIS I've wanted to tell people, teachers in particular, what a great teaching tool GIS is. It is challenging, highly motivational, and fun. More than that, because it is such a powerful motivator it can be the tool that catapults students over some longstanding educational barriers that have barred the way into the world of abstract powers of thought – a world that has eluded many students in the past and continues to do so today. This is the reason for my interest in GIS.

The Problem

We are all aware of the poor performance of American students on tests purported to measure competence in science. As weak as this performance has been we have seen recently in the news that these tests were flawed and sometimes even designed to inflate test scores. This is not a pretty picture. We should and we can use existing teaching methodologies and tools that will build cognitive substance and power in the minds and performance of students.

An Approach to Solution

What makes me think that GIS can be of value in helping teachers accomplish these objectives? My background includes classroom teaching that spans all age groups as well as in- depth graduate study in cognition and learning. These experiences prepared me to see the contributions inherent in GIS. GIS occupies a position that straddles both the concrete and the abstract worlds of thought. This characteristic of GIS gives students, the opportunity to benefit from solving problems that they can experience in the concrete world and then translate into the abstract world. In this paper I propose to demonstrate how this might be accomplished.

Objectives
The objectives promoted by this paper are 1)the teaching of abstract concepts, relationships, and mental models that form the basis of rigorous, creative scientific thought, and 2) promote the application of modern GIS/GPS technology and software to accomplish the first objective. Based upon my experience with various types of GIS software as well as online coursework, I can see how the range of cognitive processes inherent in this technology can be turned to the service of these objectives.

Rationale
There are three ways to achieve objective one above. These are: 1) traditional education contributions, 2) general training in GIS, and 3) formally integrated GIS designed explicitly for building abstract cognitive models through a challenging and gratifying experience. This paper will examine each of these methods to show there potential contribution to meeting this objective.

Traditional Approach

Working through a well planned Earth Science/Geography Problem step by step the student gradually constructs a set of concepts and relationships and finally an abstract mental model that integrates relevant geophysical concepts and relationships. Once created, this model can be held in mind while the student performs mental operations on the model. These operations may be expressed verbally, mathematically, or in images, but the student should be able to integrate all three forms.

The teacher’s role in this process is to present first a perception shaping image with attendant and appropriate motivation and logic that provides both the emotional and logical reasons as well as the necessity for engaging this model on the progression of levels that will lead to the mastery of the model and subsequent ability to apply the model in various creative problem solving applications. One way of doing this is a good story. Of course, the model presented in the story must be scientifically sound. An example of such a story is found in the example below. This model is just a sample of what the teacher needs in his/her head in order to guide the student along the path of discovery - discovery of self as well as discovery and construction of an ongoing world view. Also, without doubt, there is ongoing construction of a new self.

The Example
In this example I will demonstrate how The Traditional Approach can be used to teach two or three abstract concepts. To go beyond that would require a much more complex and time consuming model, while two concepts will serve to illustrate the idea. The idea for this lesson occurred to me when I discovered that many college students (tested in the classroom situation) were unable to identify the direction in which their own shadow would fall if they were standing outside. Obviously these students did not understand the concepts of longitude and latitude as well as other spatial relations, and certainly ***did not***

posses a mental model of Earth-sun relations. At first I was shocked at this discovery. Then I set about to design a program that would correct the problem. I consider the absence of such mental abstractions as these to be debilitating to people who have to understand and solve problems deriving from global warming, economic globalization, mass migrations etc. Not only are such deficiencies debilitating to the individual, such deficiencies are undermining our economy and our democracy.

In order to address this problem I first developed a traditional approach to teaching this specific mental model. This teaching model works fine, but only teaches one abstract mental model. Remember, what I am after is a model that exits in the mind as a mental image. These mental images comprise much of the figurative content of our thoughts – the forms and shapes of objects at the concrete level and the form that shows the relationships of a set of concepts at the abstract and theoretical levels. These features of thought can be developed at the imitative level and nurtured to at the more abstract creative and logical levels, and there is an essential need for this if students are to aspire to becoming creative scientist.

Let's take a look
Problem Title: Kidnapped
It is the end of June and you have been kidnapped and taken in a flying saucer to a laboratory in part of the Earth that is strange to your. You have no idea where you are or which direction to go if you could escape.

On your second day of captivity you are allowed to walk around inside the fence enclosing the laboratory grounds. Your walk is limited to 5 minutes at noon. The lab is a perfect cube made of solid concrete walls with no windows.

What you see is unbelievable. On one side the laboratory grounds are bordered by a beautiful sea. For a moment you pause, lean against the warm wall of the lab and think about your predicament. Then you move on to explore the trap you are in.

The opposite side is bordered by a searing desert. You stop and pluck a little flower from the shadows at the base of the building and reflect on its beauty.

As you face the desert you have on your left a rugged mountain range and opposite that is a snow field. Your time is about up but you want to look at the mountains so you Walk to that side of the building, lean against the wall and scrutinize the landscape. The coolness of the wall is restful. You hate to leave but they order you inside. It is 2.5 minutes past noon.

Several types of transportation equipment are available: trail bikes, snow mobiles, dune buggies. If you escape which would you choose?

Later in the day you hear your captors talking and discover that they have created this place as an artificial landscape with different types of treacherous barriers five mile across to test human survival skills. The site of the laboratory is located in a remote area

20 miles from your hometown. If you could cross the barrier, you would be home free. The only way out is due east if you use the appropriate vehicle.

Which form of transportation will you choose? ***At this point students have to make a decision based upon an abstract*** model. Then analysis follows, and learning occurs. The model will always work. The question is: can it be improved? Of course, you can see that careful examination of this problem with adequate instruction would enable the student to develop understanding of latitude, longitude, sun angle, time, etc. However there is more to be gained. Let's look at level two.

General Training in GIS

There is much to be gained by moving from the traditional education approach to a curriculum that incorporates GIS training. In addition to the technical competence developed by mastering this software, students will learn many of the cognitive processes identified above and begin applying them intuitively to their academic work. Certainly, this is not a difficult thing to do. Off the shelf resources for such an approach are plentiful and ready to go.

As a teacher I would prefer to combine online and computerized programmed courses with classroom instruction. The classroom instruction should include both theoretical and related hands-on learning with ample opportunity for the messier kinds of questions and discussions that are bound to occur when students meet abstract, ambiguous material. Further, this work should be based upon a well written text that can serve as a guide and reference.

An example of the value of GIS is its power for developing operational level cognitive powers beginning with ***observational*** skills, seeing details for example. Another example of this is being able to ***identify*** and ***infer*** the meaning of an abstract concept or relationship, such as the rotation of an object on the map as well as numerous other ***spatial relations***. Does rotating a store building on a map change a significant relationship? What happens if a concept is misused or misunderstood? That's easy, the student fails in developing a solution or develops a wrong solution; and must review the nature of the problem and rethink this step then develop a new answer. Thus we see the value of ***redundancies***. We've all been through this many times. Gradually we eventually learn to see the details and we learn to transfer this search and rethinking of the problem to the meanings of the concepts we read. In effect we ***generalize*** from one mapping activity to another mapping activity and to other forms of learning as well. What GIS does is: it gives us multiple experiences in working with a variety of relationships and/or concepts and by demanding ***logical necessity*** it requires us to get certain results. If we fail to get the correct result the programmed learning format will make us aware of the problem and give us the opportunity to rework the problem while it is still fresh on our minds. Then, of course, when the student has the opportunity to discuss learning experiences such as this with a well informed person who also has the knowledge and patience of a teacher, the student will be lead into discovering new connections with more material, and will build more powerful abstract models. If, however, the student is unfortunate enough to have teachers that don't understand these things, then all these wonderful intellectual processes may never be developed and the wonderful power of another mind will be lost. Without doubt there is a need for application of this technology and accompanying teacher guidance if we wish to build a complex of neural pathways that will serve as the infrastructure for scientific thinking and creative problem solving.

This process can begin early in school, certainly by the third grade. Third, $4^{th,}$ and 5^{th} grade students will benefit greatly in learning concrete concepts such as location of objects, pathways, concrete cause-effect relationships, and compass directions, etc. The 6^{th}, 7^{th}, and 8^{th} grade students as well as high school students can learn a complex series of relationships and the operational models that integrate these relationships into a functioning whole. This is heavy duty stuff because it lays the essential groundwork for creating new abstract operational models that fit the real world. This is the type of thinking that will be required to solve the problems relating to such things as global economy, climate warming, and those problems of cultural diversity.

So, GIS instruction yields great benefits even when we fail to capitalize on in its full potential. The question is: can we do more with it to benefit the student? Yes, we could design specific GIS programs to develop well designed cognitive models.

Formal Integration of Traditional Models and GIS

So, the Traditional approach works, but we only develop one very brief model. The General GIS approach works, and the students learn much, but they do not bring much of the abstract cognitive knowledge into conscious level thought.

What if we formally integrated the GIS component into teaching not only the technical content of GIS, but the abstract cognitive concepts as well? We could greatly expand the number of concepts and models developed by students. Further, this third approach, I think, could be pursued by the educational community as a team effort

Teachers, working in coordination, could design a great variety of these abstract models, build them into a GIS format and have the best of both worlds. Shared research would produce a large body of GIS based activities that would go far to correct some of the problems that contributes to the dysfunctional elements in the educational process. First and foremost, it could make education exciting for many that now find it boring, unstimulating, and irrelevant. Students would develop a great variety of abstract mental models, and as they found them useful in solving problems many would grow to the point of automatically modeling the world. What would modeling the world at an abstract and hypothetical level accomplish? Well, if we are to take a ***proactive*** approach to solving such problems as global warming (some people don't get this) this is what we must do. If we are not capable of this approach, we can only react to events as they happen to us.

So, what have I demonstrated? First, traditional education is a definite tried and true method for teaching complex abstractions. The problem with that method is one teacher can only teach a limited number of such models. As good as the students may be they still do not get from the educational system all that they are capable of learning much less all that they need to keep this country and democracy in a position of world leadership. .

Two, we could use traditional models along with standard GIS programs, and that that would greatly expand students' conscious and intuitive knowledge of abstract models. In addition they would have technical competence in GIS plus significant increases in intuitive cognitive processes.

Three, Formal integration of GIS with a universe of abstract mental models representing various human and environmental processes would enable students to raise to a much higher level of creative and scientific thanking than will ever be achieved otherwise.

Summary

At this point I have shown that the traditional model is successful in teaching one type of mental model. Based upon my personal experience in applied cognitive science I have concluded that general experience with GIS would improve this performance. The suggestion I wish to promote at this point is that well designed GIS exercises would vastly improve the cognitive performance of students and bring them to a level where abstract model building rises to the level of creative science. This remains to be tested.

Basically, GIS provides the teacher with a powerful tool that, in connection with the teacher's professional expertise, enables the teacher to motivate and guide students in making concrete observations on the real world that then becomes an abstract image in the mind, an image that can be formed and reformed until it becomes an acceptable mathematical fit with the real world. It can subsequently be tested by the student at progressively appropriate levels of mathematical challenge. Furthermore, this kind of knowledge can be used in a sophisticated scientific manner to predict future world events, and even reform extent forms that are no longer viable or perhaps even potentially destructive, i.e. climate warming.

Hopefully, I have shown how the above processes can become a viable part of the foundation upon which more powerful models of abstract thought can be created.   Such models, I believe, will give teachers a focal point around which to work and share effort in building a body of materials that will enable students to perform competently and creatively to solve the awesome problems facing humanity, while at the same time experiencing the joy and gratification of robust intellectual exercise.