Learning in Task-Structured Curricula

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Abstract: In this paper, we discuss issues relating to what we call "task-structured curricula." In contrast to traditional content-structured curricula, a task-structured curriculum is organized around goals, problems, and questions that cut across multiple areas of traditional content. Our focus, here is on two specific issues. First, we work to elucidate differences between the content "covered" in task-structured and content-structured curricula. Second, we address what we call the bootstrapping problem: How can we expect students to work on problems and issues that cut across multiple disciplines, if we have not already provided them with a solid foundation in these disciplines? We make our points by describing a curriculum developed by the Global Warming Project, and by presenting empirical results of clinical interviews conducted with students engaged in this curriculum.

Keywords: learning theory, learning environments, science education

Introduction

Many of the recent innovations in K-12 science instruction share the common goal of embedding classroom learning within rich contexts that students find both intellectually and socially meaningful. Though curricular models vary greatly, many efforts to achieve this goal share an important feature: Rather than being organized around a traditional disciplinary structure, these curricula are organized around a task. This approach has been given many names and has taken many forms; these include "anchored" or "problem-based" instruction, (Barron et al., 1998; Williams, 1992) "project-based" instruction, (Krajcik, Czerniak, & Berger, 1999) "learning by design," (Harel, 1991; Sherin, diSessa, & Hammer, 1993), and "goal-based scenarios" (Schank, Fano, Bell, & Jona, 1993/1994). In all of these approaches, the curriculum is not designed as a systematic progression through a list of traditional content topics. Instead, the structure of the curriculum is provided by problems, goals, or issues that cut across multiple traditional areas of content. We call curricula that are organized around problems, goals, and issues *task-structured*, as opposed to traditional *content-structured,* curricula.

In abandoning the content-structured approach, we should be aware that we are proposing a dramatic change, and setting out on somewhat uncertain ground. There are at least two important inter-related issues to consider. First, by its nature, a task-structured curriculum will address a different slice of content than any content-structured curriculum. Thus, we must carefully consider whether the specific changes in what is addressed are desirable. Second, even if we are happy with what a specific task-structure curriculum might, in principle, address, there are significant reasons to be skeptical that any particular task-structured curriculum will be successful in achieving its learning goals. How can we expect students to work on problems and issues that cut across multiple disciplines if we have not already provided them with a solid foundation in these disciplines? We call this second issue the "bootstrapping" problem.

In this paper, we address each of these two issues. In the first two parts of the paper, we work to elucidate differences between the content covered in task-structured and content-structured curricula. First, we describe two key differences in the way that task-structured and traditional content-structured curricula deal with content. Then, in the section that follows, we illustrate these differences using a task-structured curriculum that we have developed. Finally, in the last section of this paper, we address the bootstrapping problem. In particular, we will describe some preliminary results of our efforts to empirically track the development of disciplinary content understanding by students in a task-structured curriculum.

The Nature of Content in a Task-structured Curriculum

In the case of content-structured curricula, it is comparatively easy to answer the question: What content is taught by this curriculum? This question is relatively easy to answer because a content-structured curriculum is organized as a progression through content; you can thus "see" the content just by looking at the heading of each portion of the curriculum materials. In contrast, it is somewhat more difficult to see what is taught in a task-structured curriculum. The task and its sub-components may not correspond, in any obvious way, to traditional elements of subject matter.

For illustration, consider problem-based medical instruction (Barrows & Tamblyn, 1980; Williams, 1992). In this innovative approach, the learning takes place in the context of medical problems. Students are given the medical history of a patient, including a list of symptoms, and they investigate the potential causes of the patient's complaints. In the course of these investigations, they typically conduct and share research that cuts across several traditional content areas. For example, they might have to learn a little anatomy, some biochemistry, etc. This is generally true of task-structured curricula; the content understanding required to solve a meaningful task tends to cut across traditional areas of content.

Another important issue for task-structured curricula is the question of "depth." In a task-structured curriculum, the task not only dictates what content must be covered, it also dictates the manner—or depth—in which the various portions of disciplinary content must be understood by students. Consider, again, the example of problem-based medical instruction, and suppose that a particular medical problem requires students to understand a case in which a patient appears to have suffered significant blood loss. For this case, students might need to know about some aspects of the cardiovascular system in great detail, such as hemodynamics and the properties of the heart as a pump. In contrast, they might only need a cursory understanding of other related topics, such as how, exactly, the muscles in the heart allow it to exhibit its particular pump-like properties.

This picture contrasts strongly with what one finds in a content-structured curriculum. In a content-structure curriculum, we attempt to build up content in a manner that we believe reflects the a priori structure of a discipline. Furthermore, we attempt to address a content area to a certain, uniform, depth. In contrast, in a task-structured curriculum, the depth to which various portions of a discipline are covered is much more idiosyncratic. Some issues will be covered in great depth while, in other places, students will learn just enough to "get by."

For these reasons, the selection of a task is the critical decision in the design of task-structured curricula. The decision must align the motivation provided by the task with the particular content breadth and depth goals of the designers. Different approaches to task-structured curriculum design use different strategies for selecting tasks and designing learning activities around those tasks. For example, project-based science is designed around a "driving question" that students research. Anchored instruction is designed around a realistic "macrocontext" which poses a problem that students must solve. Goal-based scenarios provide learners with a role to play in a simulated scenario and a goal to achieve within that scenario.

The Global Warming Project

In this paper, we present the Global Warming Project as an example of a task-structured curriculum. The Global Warming Project is an 8-10 week middle school science unit created by the Center for Learning Technologies in Urban Schools at Northwestern University in collaboration with the Chicago Public Schools. In this section, we describe the task that structures the GWP, how that task organizes content in the GWP, and how it determined the depth of content understanding that the GWP requires.

The Task

In the GWP, students adopt the role of scientific advisors to heads of state for both developing and industrialized nations. The students are asked to prepare scientific briefings for these leaders' respective countries that will help them to prepare a policy for responding to the threat of global climate change. This task was selected with three goals in mind: (1) Engage students, (2) create a need for students to master specific learning objectives, and (3) provide an opportunity for students to apply their new understanding. The topic of global warming was selected because it offered an opportunity to address several important content standards in the Earth and physical sciences, because it is a matter of current scientific controversy, and because its significant social implications are engaging to

students. However, with such significant social implications, there was a risk that students would focus too much on the social and policy issues, rather than the science. Therefore, the role of scientific advisor was chosen over a number of alternatives, such as international treaty negotiator, because it focuses students more directly on the scientific issues, while still taking advantage of the social issues to provide motivation and context. The task of advising a non-scientist policymaker requires that the students understand the scientific content, be able to apply it in order to generate policy recommendations for a specific head of state, and to be able to communicate it effectively.

The task in the GWP creates a demand for understanding of content that is typically taught separately in biology, chemistry, physics, and Earth science courses. These topics include: radiative energy transfer, reflectivity, and absorption; respiration, photosynthesis, decomposition, and the carbon cycle; and Earth's energy balance, the hydrological cycle, and the greenhouse effect. To understand the potential causes and mitigation strategies for global warming, students must understand the transfer of energy as it passes into, through, and out of the Earth-atmosphere system. They must understand the factors that determine how much solar energy is reflected back into space and how much is absorbed by the Earth's surface and atmosphere. They must also understand the role that atmospheric "greenhouse" gases play in trapping the resultant heat within the Earth-atmosphere system. Finally, they must understand the natural and anthropogenic processes that cause greenhouse gases to be emitted into and removed from the atmosphere. It is easy to see that this selection of content around the threat of global warming leads to a very different slice of content than would be found in any traditional disciplinary curriculum.

How the Task Organizes Content

The organization of the global warming curriculum reflects both the nature of the task and the nature of the phenomenon of global warming. The high-level organization of the curriculum is determined by the scientific advising task. The students must prepare briefings on three questions, *How could we tell if Earth were getting warmer? What might be causing global warming? What are the predicted implications of global warming for individual countries and what solution strategies should they pursue?* These three questions represent the primary sequence of the curriculum. To answer the first question, students investigate the challenges to measuring climate change (i.e. distinguishing between natural and "unnatural" variations). To answer the second question, they study the processes that regulate climate on Earth and the impact of human activities on them. To answer the third question, they investigate scientists' predictions for global climate change and explore strategies for reducing global warming and its impacts. Within each of those major organizational units, the content is organized by the phenomena under investigation. For example, in their investigations of climate regulation, the sequencing of the learning activities reflects the flow of energy through the Earth-atmosphere system. This sequence begins with investigations of incoming solar energy, followed by reflectivity and absorption, then the greenhouse effect and anthropogenic emissions of greenhouse gases.

Choices About Depth

In the design of the GWP, the task determined both the selection of content and the depth of understanding that was required. Students must understand the content well enough to successfully complete their task of explaining to a policymaker how human activities may be contributing to global climate change and recommending strategies for responding to the threat of global warming that might reduce its magnitude or impact. In the case of some content, this goal required students to develop a detailed understanding of scientific phenomena. In other cases, a superficial understanding was sufficient.

For example, human activities have altered Earth's surface and its reflectivity of incoming solar energy—the degree to which it reflects rather than absorbs the energy that the Earth receives from the sun in the form of light. To understand the impact of changes in reflectivity, we decided that it was necessary for students to understand a little about light; they needed to understand that light carries energy, that it must be either absorbed or reflected when it reaches Earth's surface, that lighter colors reflect and darker colors absorb more light, and that absorbed light causes the Earth to warm. For the purposes of the GWP, we felt that this simple understanding was sufficient, and that a more detailed understanding of light, energy, and heat was not necessary for the task. Similarly, we decided that it was important that students know how photosynthesis, respiration, and combustion of fossil fuels influence carbon dioxide levels in the atmosphere, because these processes are affected by human activities. On the other hand, we did not feel it was necessary for students to understand how greenhouse gases absorb and emit long-wave radiation at a

molecular level. It is important to point out that these decisions about depth were made in the context of a standards-based design process. However, where standards can be frustratingly vague about what level of knowledge they require, the specific task provided us with concrete goals to guide the curriculum design process.

Empirical Investigation

In this last part of this paper, we turn to the bootstrapping problem. As described above, for students to engage in the task that underlies the GWP curriculum, they need a broad background in content. Because so much is required, the GWP needed to make choices about what background it would attempt to provide, and how deeply it would go in various places. These choices essentially divide the required background knowledge into three categories: (1) Knowledge and capabilities that we presume that students will possess prior to entry, (2) knowledge that we assume they will "pick up," and (3) knowledge that is directly addressed, in some manner, by the curriculum.

Each of these categories can present a target for empirical studies of learning in a task-structured curriculum. We can ask: Do students, in fact, possess the knowledge and capabilities that we presumed upon entry? Do they pick up what we hoped they would pick up? Do they learn what we attempted to address explicitly?

Here, we will say a little about our experience in attempting to answer these questions for the Global Warming project. Our primary purpose here is not to evaluate the Global Warming curriculum and we will not attempt to provide definitive answers to these questions. Rather, our goal here is to give a feel for the type of analysis that is involved. Furthermore, we focus on the first two questions since these are the ones that are most interesting from the point-of-view of making comparisons to a content-structured curriculum.

In order to answer the above questions, we have been designing clinical interviews to be conducted with students at various points during the Global Warming curriculum. To date, our interview research has been focused around one specific portion of the Global Warming curriculum. This portion of the curriculum was, in large part, designed to help students understand how the amount of incoming solar energy varies across the surface of the Earth and why it varies in this manner. In brief, the main point is that light from the sun strikes different places on the Earth at different angles. Where the light strikes more indirectly, the intensity is less (refer to Figure 1). Note that understanding the argument outlined in Figure 1 is dependent on a significant amount of background knowledge. For example, it is helpful to have some understanding of the structure of the Earth-Sun system (i.e., the Earth is a big ball that moves in a circle around the Sun, which is also a big ball). In addition, it is also necessary that the students have some understanding of the nature of light. The understanding of the Earth-Sun system is something that the curriculum presumes students will have upon entry. The understanding of the nature of light is something we hope they will have or pick up as the unit proceeds.
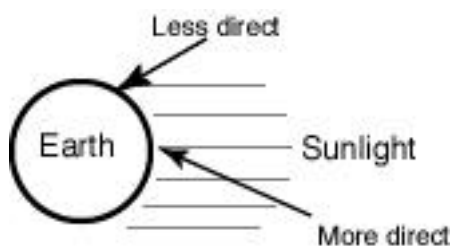

Figure 1. Sunlight striking the Earth.

The interviews were designed to get at issues of this sort; we asked questions designed to elicit students' models of the Earth-Sun system. For example, one such question asked students to explain the seasons and why, in particular, it is warmer in the summer and colder in the winter. We also asked questions to get at students' understanding of the nature of light. Some of these questions asked students to imagine a simple situation in which there is someone holding a light bulb in an otherwise dark, large room.

So, did the students entering our curriculum have a sufficient model of the Earth-Sun system? Did they know that the Earth, which is a sphere, travels around the Sun, which is also a sphere? In this case, there is really not that much to tell; this assumption proved to be largely unproblematic. All of the students in this age group

knew that the Earth and Sun were spheres, as we would expect from prior research in this area (Vosniadou & Brewer, 1992). Not all students were as clear about the nature of the Earth's motion; some seemed not to know that the earth rotates on its axis and revolves around the sun. However, it turns out that this is not essential knowledge for the Global Warming curriculum.

However, the nature of students' understanding of light was more interesting and variable. As stated above, one set of questions asked students to imagine a simple situation in which there is someone holding a light bulb in an otherwise dark, large room. The students were asked to imagine, first, that the person holding the bulb is standing relatively close to a wall and that the light shines on the wall. Then they were told to imagine that the person gradually walks away from the all. Finally, the interviewer would ask: "How does what you see on the wall change as I walk backwards from the wall?" The GWP curriculum was designed with the implicit assumption that students understood light as radiating out from a central source, covering a larger area with less intensity the greater the distance from the light source. In fact, most students, when asked the moving light bulb question, responded in a manner that is consistent with this model, that is, the farther the bulb is away from the wall, the more the light spreads out and the dimmer it appears. However, some students did respond in more surprising ways. For example, one student, Dedra, said that there would be an illuminated area on the wall, and that this would get *smaller* as the light bulb moved away from the wall (Figure 2). Here is an excerpt from her response:

> I: How does what you see on the wall change, as I walk backwards from the wall?
> D: Like, the reflection gets smaller? … gets smaller when you move back.
> I: … there's like a circle on the wall that you see?
> D: Yeah.
> I: And how does that circle change, it gets-
> D: It gets smaller until it's gone.

When asked why the circle on the wall gets smaller Dedra responded:

> D: Because you're moving further away from the wall.
> I: Uh-huh.
> D: And the light only shines like in an amount of space.

We believe that Dedra, like some other students, is answering these questions as if she is applying what we call the "sphere of illumination" model. In this model, there is no sense in which the light travels from the light bulb to the wall. Instead, when the light is turned on, it instantaneously creates an illuminated area of fixed size around it; there is a sphere of light around the bulb. Understanding the model in this way can help us to understand, for example, why Dedra says that "light only shines like in an amount of space." It can also help us to understand why she says that the illuminated area on the wall will get smaller. As the bulb moves away from the wall, the intersection of the sphere with the wall is a smaller and smaller circle. Figure 2 shows a drawing that Dedra made to illustrate this situation.
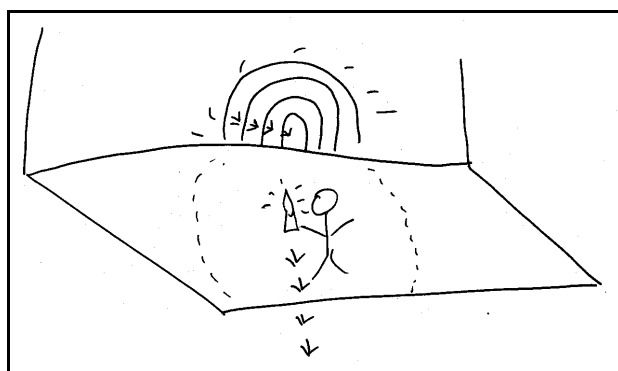

Figure 2. Dedra's pre-interview drawing showing the reduction in size of the illuminated wall area
as the light is moved away from the wall.

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One of Dedra's later answers is also very telling. As part of the interview, the students were asked about what happens at the instant the light bulb is turned on. In particular, they were asked if the wall is illuminated immediately or if there would be a short delay. The majority of students responded that there would be a very short delay corresponding to the time it takes for the light to travel from the bulb to the wall. But students reasoning from a sphere of illumination model said that the wall would be illuminated immediately.

I: ... At the instant that the bulb comes on does the light appear on the wall right away? Or is there like a little delay from when the bulb lights up until when the light's on the wall?
D: … it comes directly on the wall.
I: So it should be right at that instant.
D: Hm-mm. … It would come right away- the reflection would come right on the wall.

The existence of this alternative model casts doubt on some of the assumptions built into the Global Warming curriculum. What happens to students that possess an alternative model of this sort? Is their understanding of light sufficient to support the learning that must go on in the curriculum? Will they "pick up" a more useful model of light?

To answer these questions, we can look at the results of an interview with Dedra following a series of activities in which students investigate the influence of angle of incidence and color on light absorption. In this follow-up interview, we asked a series of questions that were similar to those in the earlier interview. When asked what would happen when the bulb is moved away from the wall, Dedra responded that the illuminated area would get bigger rather than smaller, and that the intensity would decrease (Figure 3):

D: Like the reflection on the lamp gets bigger. And the farther you go away the dimmer the light gets on the wall.
…
D: Cause they're further from the wall. They don't hit the wall at the same angle and they, um, they're not as strong.
I: ... why are they not as strong?
D: Because it's further away from the wall. And it hits it at an angle.

In fact, throughout the follow-up interview, Dedra answered questions as if she was applying a model in which light travels outward from a source, decreasing in intensity.
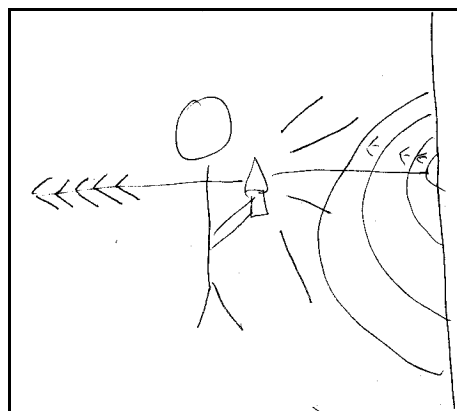

Figure 3. Dedra's post-test drawing showing an expanding area of illumination as the light is moved away from the wall.

Some care is needed in interpreting observations of this sort. It is not necessarily correct to say that, before the summer course, Dedra "had" one model and, after the course, she had the other. The range of possibilities is

much more complicated. For example, both models may, in some sense, have been constructed during the interview. Furthermore, it is possible that both ways of reasoning were accessible to Dedra prior to the course. It might have been that, with just a little prodding, Dedra could have reasoned about light with a more appropriate model, even before the course.

However, at the least, these observations suggest some shift in how Dedra *tends* to reason about light. In addition, it suggests that the presumptions built into the curriculum concerning what must be addressed explicitly might be reasonable. Either Dedra learned to think of light as something that travels outward from a source, or she was always capable of thinking of light this way, given a little prodding. In either case, it was not necessary for the curriculum to explicitly teach Dedra about the nature of light.

We can also look at how Dedra fared in the curriculum; in particular, we can look at her understanding of climate, and especially the role of incoming solar energy. The results here were also encouraging. For example, during the post-interview, Dedra was asked why it is generally warmer in Florida than it is in Alaska. Her responses were largely as we would have hoped:

D: Probably cause Alaska doesn't get direct sun rays like Florida does.

Of course, a single, brief case study of this sort is far short of what is necessary to validate the assumptions built into a curriculum. Much more is needed, and our work will continue. Our goal in this paper has only been to illustrate the type of analysis and empirical work that we believe is required in order to understanding the learning that occurs in task-structured curricula.

Conclusion

Task-structured curricula embody different assumptions concerning the selection, organization, and required depth of content. In this paper, we described our current attempts to understand and explore one of these assumptions—that rather than requiring the broad foundational understanding that traditional content-structured curricula try to build, task-structured curricula can develop understanding around the specific needs of the task, using the requirements of the task to determine the depth of understanding required for any particular portion of the content. While our early efforts are encouraging, as the example presented here demonstrates, a great deal more research will be required to explore this assumption and the others that are implicit in the task-structured curriculum approach.

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