Integrating Systems Thinking and Simulation into the Eighth Grade Science Curriculum

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Introduction

Since the fall of 1988, an approach to science curriculum delivery called Learner Directed Learning has been evolving at Orange Grove Middle School in Tucson, Arizona. Learner Directed Learning utilizes the power of Systems Thinking, a school of thought that focuses on recognizing the interconnections between parts of a system and synthesizing them into a unified whole (Systems Thinker, 1990). It is not merely a way of looking at classroom management but also a way of viewing content structure and delivery. It is a way of viewing the world.

In this paper I will try to explicate what Learner Directed Learning looks like to students and teachers, point out some of the benefits and problems to both groups, and I will try to address our communications with the wider constituency to which we are responsible.

Students

The best way to describe how Learner Directed Learning affects students, is to describe what a typical learning unit looks like.

What a unit looks like to students

The sequence for a typical unit of study includes:

a. an introduction
b. the general activities
c. a major activity
d. a summation

a. unit introduction

A new unit of study is introduced to the students as a gestalt, an entire system. The introductory discussion includes the following 4 points:

1. Why we feel the unit needs to be studied at all — how it is important in the "real world".

2. What the "major" activity of the unit is to be. It is usually one of the following:
   - a design-centered computer simulation where students design a "real world" system using the science content they have learned (i.e. — designing a new state park using natural resources knowledge; designing a resource efficient house using energy conservation and physical science knowledge.)
   - a policy-centered computer simulation where students manipulate systems input variables to determine effective policies in management issues concerning science content (i.e. — grasslands management using succession knowledge;

wildlife management using population dynamics knowledge; horse breeding using genetics knowledge.)
- a human interaction simulation where students role play, acting out scenarios or situations using what they have learned (i.e. — The Redwood Game; Fish Banks — a simulation variation on Commoner's Tragedy of the Commons.)
- multimedia presentations and/or seminars where students become "experts" on particular issues or concepts and present those to their peers.

3. What general activities are going to be done in order to develop the capacity to make the decisions required by the major activity. The activities are ones you might typically find in a standard science class, except that students conduct the activity in self-directed small groups. We generally have 5-10 different activities going on concurrently in the same classroom.

4. What the students' responsibilities (products, assessment, etc.) will be and the timelines the unit will follow (when responsibilities are due). At this point students create "jobs lists" listing their responsibilities, what they entail, and when they need to be completed.

b. general activities

The general activities are well defined but loosely structured tasks. It is always clear what is expected and how that activity fits into the decision making that is coming later, but it is often left to the group to determine how to complete the task so that the expectations are achieved. Activities generally are of the following types:

- wet labs
- field experiences
- computer simulations
- library/text/reference research experiences
- database construction
- multimedia direct instruction

Lab, classroom, computer and on-campus field experiences are run as concurrent sessions in a multitask classroom environment. That means that we typically have groups of 3 - 4 students working on a task that is different from the other tasks going on in the classroom. The teacher is facilitating up to 5 different activities (there are multiple copies of each activity) at one time. This sounds hectic (and sometimes does get busy!) but the tasks are carefully defined so that student groups call over the teacher only at specified junctions in the activity, or when they need clarification of instructions. The teacher's role in this environment is not to dispense information, but to help the students construct their own understanding. Students, after initial frustration about the system in the fall of the year, soon realize that solutions to most problems are up to the group itself, that the teacher will merely ask questions that help them along, not intervene to solve the problem.

Off campus field experiences are all day affairs, taken in 1 section groups (about 24 - 30 students). The flexibility of block, interdisciplinary scheduling allows us to take whole sections of students off campus at a time without having to worry about interrupting other classes or hiring substitute teachers.

c. main activity

The main activity is the denouement of the unit. It is here that the students fully make sense of why the content was covered at all. Regardless of the style or medium of the activity, several components are found in every main activity:

1. mission statements — students create goals for the level of their performance within the simulation. Many times mission statements are communicated in terms of graphs demonstrating the anticipated dynamic behavior of the activity.
2. resources — students have constant access to the resources they used and or collected during the general activities. These resources are available at any time.
3. plan — students develop plans (often using scientific thinking processes which control for variables) to do the main activity.
4. decisions — students, during the main activity, make decisions as close as possible to the same decisions made by people in the "real world". Some of these people are scientists, but many are lay people using scientific information. The explicit assumption being that our curriculum is designed to have citizens aware of the science in their everyday lives, not to make every student a scientist.
5. interpretation of results — most often these results are also in graphical form so that our students can directly compare their missions (which in some cases are hypotheses) with the actual results.
6. re-run — depending on the nature of the activity, students may need to repeat steps 3-5 if the results do not match up to their mission statement. Teachers may require students, at any time, to hypothesize why their results did meet their expectations. These explanations — even informal ones between students without teacher initiation — are rich with the science vocabulary of the content of the simulation.
7. communication of designs, ideas or results — students are constantly sharing their designs and ideas with each other during the activity. This, of course, means that we try to have them see each other as resources. That also means we do not see sharing ideas as "cheating". Once the students are pleased with the match between their mission and the results, they then plan to communicate their findings with the rest of the classroom community. There is a time at the end of the activity dedicated to formal presentations of ideas and designs.
8. constant communication with the teacher — the teacher, at any time, has the freedom to sit with a group for several minutes at a time to talk to students about what they are doing, why they are doing it and what will happen as a result of their actions.

- **Summation**

The summation sessions are a final wrap-up of the entire unit of study, pulling together all the activities.

Benefits & Problems for Students

In other words, students covered much of the same content as would be found in traditional science classrooms, but they learned it by researching, thinking, hypothesizing, making decisions and designing real world components. In addition, they learned the content not as disparate parts but as an entire system of relationships and dynamics.

More importantly, students have "experienced", at some level, how the content covered is really being used in the world. Relevancy is not something told them, but something they realize through working with the content. Additionally, each student is overtly interacting with the content in their own way, building understanding. By talking with students on individual bases, we have a great opportunity to catch misconceptions and confusions.

We have found this approach to be overwhelmingly successful with nearly all students, including mainstreamed "learning disabled" labeled students. The only problems we have encountered have been:

(1) students that are "good at school" have reported that we do not "teach" them, that they wish we would just give them the information so that they could take a test on it.

(2) some students that are not "good at school" have reported that they have to "work". Now they cannot hide in a lecture like they used to.

Teachers

Planning

Planning for our learner-directed learning units is a time consuming process, but is well worth the effort when we see the result with our students. The process we follow may seem counterintuitive to some, but structures our thinking towards student centered learning better than anything else we have tried.

The process may be thought of has having 5 steps.

1. What is the reason for the content?

We ask ourselves: "What do we want citizens to be able to do with this content?" This question helps us establish a real world basis for covering the content. This means that instead of looking at botany as a series of subunits (leaves, stems, reproduction, etc.) we ask "What do we want citizens to be able to do with the knowledge of plants?" Just the act of asking the question throws your whole focus of teaching into a different realm than the question "What do I want them to know?"

2. How is it to be Learned?

Here we ask: "What is the 'best' way to learn how to do number 1 without any constraints in time, money or reality?" This allows us to imagine ways of learning that may not be typical of most classes. Perhaps the best way to learn the human body systems is to "run" a body — be the autonomic nervous system. This, of course, is not possible in the real world — but it can be simulated. It may be the "best" way to learn how the body systems work together.

3. Can we do it?

We ask ourselves: Can we do number 2, given the time and money constraints we work with? If it is yes, then the main activity is defined. If it is no, then we take a step back, and without changing our answer to step 1, re-ask what is the "next-best" way to learn how to do number 1 without any constraints in time, money or reality. Eventually, we do come up with our main activity. If we cannot actually "do" the real thing, we often simulate it as best we can.

4. Setting the context

There are two steps in this phase. First we ask: "What decisions will citizens make or do citizens make using this content?" Another way of asking this is: "In order to do the main activity, what decisions will the student need to make?"

The second part of step 4 is to ask: "What do students have to know in order to have the capacity to make those decisions?" In other words, what sorts of science content needs to be in their heads in order to make informed decisions?

This list of decisions and knowledge determines the set of general activities the students progress through that lead up to the main activity.

5. Develop the Activities

Here we develop the activities and sequence that best leads to the knowledge that creates the understanding needed to make the decisions. The set of general activities needs to be:

- diverse in structure — a sequence of 10 hands-on labs would be difficult to manage and tie together semantically.
- diverse in mode — a variety of direct instruction, creative expression, research/data collection, interpretation activities are essential. This is essential both for varying experiences for the students and varying the management demands upon the teacher in a multitask environment.
- student directed — where teachers are needed only to guide the direction, not dispense the information.
- matched to the decision demands of the main activity.

Often, we find that we can use activities found in standard published science curriculum materials. We merely need to modify them slightly so that students can see how the activity fits into the entire gestalt we have set up. In other words we try to have students see what sorts of decisions the information learned in the activity helps them make.

Benefits and Problems for Teachers

The benefits for teachers are several:

- the learning environment is more motivating for teachers and students. When students can control much of their own learning and have a good time while doing so, classroom discipline problems drop and teachers have more time to spend with slower students. We, honestly, have virtually no behavior problems. In an open-ended survey, 70 percent of the students in our classes called the systems, learner-directed-learning units the "best part" of the school year.
- this approach is more efficient. For the past two years we have completed in March a curriculum that used to take until June to complete. This is in spite of adding more topics for the students to cover.
- teachers become creators of environments rather than dispensers of knowledge. We have found that when we are creating, we are happier with our job and work harder to make it better.

The problems for teachers, so far, have included:

- increased time demands during planning (although there is less planning during the actual unit of study.)
- increased demands to communicate what we are doing to administration, parents and other teachers. So far, the response from these groups has been overwhelmingly positive.
- teachers have to be able to tolerate more action in their classrooms as students work with each other, in independent ways.

Other Parties

One of the problems with innovations in schools in the past has been their narrow focus on just one part of the complex system we know as School. When reformers just concentrate on curriculum reform or schedule reform or administrative reform, they are missing the entire picture. The other subsystems, if not taken into account, will "push back" on the reforms trying to take hold, and push them entirely out of the picture. The history of educational reforms is littered with the corpses of pushed out programs.

Keeping this in mind, we are in constant communication with all the various subsystems we can identify, and are working with them as we develop our program. The learner directed learning described above is not an isolated set of classrooms, but is one part of a larger restructuring taking place at Orange Grove Middle School. This restructuring, utilizing the paradigms and tools of Systems Thinking, is helping to insure that learner directed learning is meeting the needs of students, parents, administrators, state curriculum guidelines and societal needs.

We constantly talk to and solicit advice from our students, parents, administrators, state curriculum coordinators, local scientists and science faculties, and community members. This advice is not merely "input", but information we use as we reconstruct our curriculum.