The Learning Molecule

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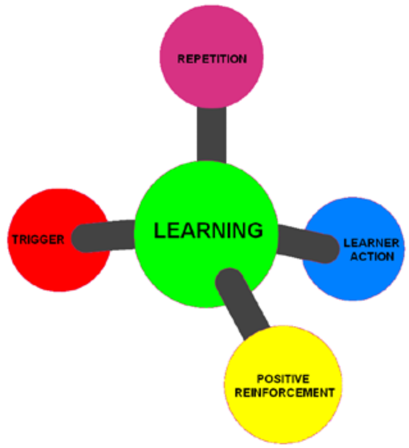


American schools are struggling. Our student achievement is spotty. Our teachers are stressed and underpaid. What's worse, our experts can't agree about what to do. There doesn't seem to be a common view of learning they can share and use as a starting point for fixing things. Maybe we have an answer.

Cybernetics and Learning

Cybernetics

If you've ever sailed, you know that no amount of teaching can replace actual time at the helm. Learning to steer is a visceral experience. The pressures of wind and waves go up and down. They change direction. And every little change throws the boat off course. Only by feeling their effects yourself do you become sensitive to their subtleties and rhythms. At first, your natural reactions with the tiller or wheel are excessive. You overcorrect, first to starboard, then to port, and the boat swings back and forth on either side of a proper course, leaving what's called a "snake wake."

Gradually, though, as you adjust to the changing pressures, you begin to meet them with increasingly subtler pushes on the helm. The boat settles down and the feedback you feel guides your reactions to make them ever finer. Looking aft, you see that your wake has straightened considerably.

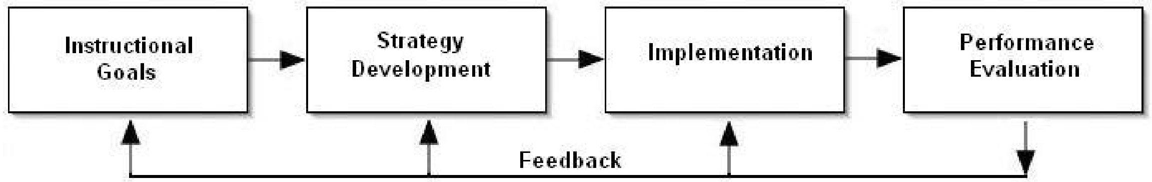
The MIT mathematician, Norbert Wiener, was greatly impressed by this interaction of helmsman, wind, and sea and the insights it provided on understanding the learning process. He relied on these insights as he pursued his study of feedback and control systems. Wiener named his new science "cybernetics," derived from the Greek word "kybernēs" for "helmsman."

Four key factors make up a feedback system:

1. A targeted state of balance or control.
2. Recognizable influences on control.
3. Identifiable responses to influences.
4. Feedback showing effects of responses.

Cybernetics and Instructional Systems

Although unintentional, Wiener's description of a feedback system paints a useful picture of a balanced and self-correcting instructional system. In the early 1960's educator Robert Glaser presented a model for instructional system design and maintenance that looks a lot like Wiener's perception.



Glaser's Model

Glaser's model begins with a statement of targeted instructional goals. He then addresses design and development of strategies for managing influences on goals. System implementation equates to Wiener's set of cybernetic learner responses. Evaluation of performance results produces feedback leading to refinement of system components. And the process is repeated.

Glaser saw the proper instructional system as a dynamic thing, closing in on optimal performance with successive iterations. His perceived interaction of goals, methods, skills, and feedback-driven responses make managing an instructional program very like steering Wiener's sailboat.

Several important implications arise from Glaser's model. It makes sense that evaluation of strategy effectiveness be in terms of initially stated program goals. Therefore, goals must be stated in measurable terms and assessment must adhere to these terms. The model also suggests that, based on evaluative feedback, a learner may individually engage in alternative strategies until goals are met.

The model also makes a powerful statement about assessment in general. To Glaser, the purpose of testing is twofold:

1. Indicates extent to which instructional goals have been met.
2. Gain information leading to improvement of instructional strategies.

Attention to Details

Glaser's model of an instructional system compares nicely to Wiener's cybernetics, but it's fraught with practical complexities and questions. How do you state objectives in terms you can use in later measurements? How do you account for a wide set of variables affecting performance? What about learners who come with differing prerequisite skills?

Two educational psychologists, Robert F. Mager and Robert M. Gagne, provided many answers to these questions. Mager developed exhaustive guidelines pertaining to objective specification. He gives valuable insight into the value of specific and measurable goal definitions. Gagne contributed to understanding learning hierarchies and the sequencing of instructional strategies according to how skills and concepts build on one another.

"We know how to farm better than we are able to farm." Franklyn S. Barry, Syracuse Superintendent of Schools, 1968

When the findings and recommendations of Wiener, Glaser, et al were published, they were useful but frustrating guides to educational thinkers. The informational requirements for handling feedback and managing individualized processes were far beyond the administrative capacities of schools and teachers. At the time, computers that could conceivably manage the task were expensive and filled rooms. Consequently, feedback-driven instruction was seen to be beyond the means of schools to actually put into practice. As time passed, attention to it diminished until it became little more than a footnote in teacher education programs.

Cybernetics and the Learning Molecule

The constraints on implementation of feedback-based instruction do not affect its validity. Educators must still make decisions about goals, standards, prerequisites, testing, etc. Just being aware of the roles of these factors and how they interact in well-designed systems helps us deal with them in real world situations.

While Glaser and the others were studying the makeup of instructional systems and providing insights into meaningful, productive objectives and effective instructional sequencing, another scientist, B. F. Skinner, was working on the most basic question of all. How do people learn? In other words, what happens in the "Implementation" stage of Glaser's model?

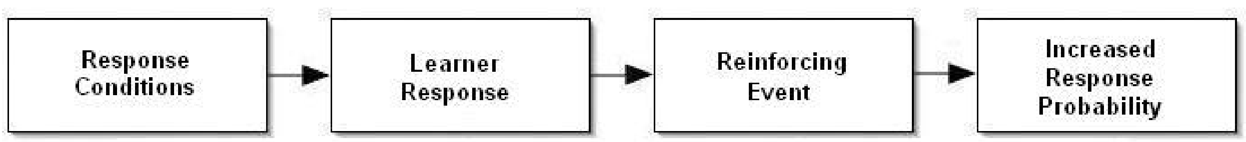
The answer he gives us is neat, simple, and its alignment with Wiener's and Glaser's work is profound. This may not be so surprising since all of the theorists mentioned were familiar with Skinner's work and likely influenced by it.

Skinner describes a simple learning dynamic. A learner possesses a repertoire of potential responses reflecting skills, knowledge, or feelings. These responses are either inherent or learned, and the potential for their occurrence depends on conditions facing the learner at any given time. Existence of a set of conditions serves to trigger responses. The potential for a particular response is increased by the occurrence of a subsequent reinforcing event, the more frequent and immediate the reinforcement, the stronger its effect.

In that Skinner's "conditions for learning" constitute a "desired state" they are akin to the "Instructional Goals" specified in Glaser's model. Likewise, the selection and execution of a learner response as viewed by Skinner parallel Glaser's "Strategy Development" and "Implementation." Finally, the effect of reinforcement on future responses aligns directly with the influence of evaluation and feedback

Skinner's dynamic closely matches Glaser's larger process. Both begin with the setting of a stage for action. The second steps of both involve specifics of the action. Next come execution and results, followed by measured effects of those results.

Skinner's construction of a learning event and the interaction of its elements describe a process so fundamental it can be viewed as the basic building block of the learning. Think of it as the learning "molecule."



Skinner's Learning Molecule

A Sailor Learns to Steer

How does the learning molecule work for our new sailor learning to steer? Let's start with Response Conditions. The options are: a light breeze versus a strong wind, wind and waves coming from behind versus ahead, and small waves versus big ones. Other possible conditional variations might include things like mast rake, sail area, and wheel versus tiller steering.

The responses the new helmsman is trying to learn begin with sensing the changing pressures on the helm and the boat. He then wants to push back on those pressures but not too little and not too much. Whatever he does the pressures abate momentarily. That ebb in pressure is what he wants and it is reinforcing to him.

Left on their own, sailboats usually head up into the wind. So our helmsman can expect that whatever he just did, he's going to get a chance to do again in just a couple of seconds. If he overreacted it may be a few seconds more, less if he didn't push back enough. In either case, the rhythm of the operation is off. But…. the longer he stays at it the closer he gets to getting it right. The rhythm becomes even and the boat feels balanced. This rhythm and balance is very reinforcing so the more often it happens the more often it happens. The helmsman is learning. Of course, under different conditions the rhythms and pressures will vary so he'll have to learn some slightly adjusted responses.

Can we use the learning molecule to describe learning math? The solutions to most math problems usually involve a multi-step process. It's safe to say that each step will likely involve one or more basic operations. Consequently, we should be able to identify reinforcers for each of these and for the completion of the final step.

When solving problems, large or small, confirmation of accuracy is a powerful reinforcer. It's the feeling we get when our answer matches the one in the back of the book. In multi-step processes this vital final feedback does not become available until completion of the last step. The reinforcer for an intermediate step is the strong sense of correctness at that step and therefore closer to the final result. Suppose, though, we haven't worked enough of a given type of problem to be sure of the process required. Or we lack confidence in our basic skill so our expectation of being correct is not strong. The intermediate reinforcers we need to sustain the activity aren't as strong, and we profit less from the learning experience. We may give up altogether.

Take an example from our own experience. Suppose we have an invitation to visit a friend for the first time. Few of us look forward to driving to an unfamiliar destination, but if our host provides directions with streets and landmarks we'll give it a try. As we travel, each landmark brings a small surge of satisfaction. Spotting it increases our comfort level and acts as an intermediate reinforcing event. If they share any common features such as street sign placement at intersections, the reinforcement of seeing one landmark increases the likelihood that we'll spot the next one. On the other hand, if we miss a few of these landmarks we become frustrated and closer to calling on a cell phone or stopping for directions. Finally, we arrive and identify the number on our host's house. That brings an even stronger surge of satisfaction.

When we get there, our host's first question is did we have trouble finding the way. Our answer constitutes a brief synopsis of what happened and might cause the host to review his directions. This wrap-up, along with the trip's reinforcing success will make the next one easier. When that happens, we'll notice the same landmarks and we'll also remember things we saw before. We'll hardly give the phone a thought. After one or two more visits we may not even look at the directions. We will have learned the way.

Weiner, Glaser, and Skinner would likely concur that this learning experience involved:

1. Our motivation for the trip and a set of directions with. (Conditions)

2. Our ability to spot landmarks along the way. (Intermediate and Final Responses)

3. The satisfaction associated with spotting landmarks. (Reinforcing Events/Feedback)

4. Our host's curiosity about his directions. (Feedback)

Let's Farm Right

Skinner's description of a learning event becomes a powerful tool for instructional designers. It provides a basis for analyzing strategies and discussing them clearly and objectively. It offers a useful context for Mager's excellent books on instructional objectives. It also gives us insight into Gagne's findings on instructional sequencing.

Information technology gives us the power to manage instructional processes in ways we couldn’t imagine two decades ago. It means we can, metaphorically, farm as well as we know how to. With the elements of the learning molecule in mind we can develop testing methods that do more than show what students know. With technology, we can generate feedback that show where instructional strategies worked well and where they need improvement.

Most importantly, if the learning molecule helps instructional experts agree on how learning works they’ll have better prospects for giving our schools the learning systems they need.