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ABSTRACT

Understanding why students are not naturally and easily able to generalize or apply what they have learned in other situations involves understanding what teachers want their students to learn; what learning is; what teaching is; and what is involved in generalizing or applying what has been learned. Research in educational psychology identifies three major types of knowledge: rote (i.e., memorization), declarative (i.e., knowledge of concepts) and procedural (i.e., knowledge of a physical or intellectual process, method, or skill). Knowledge does not automatically transfer between declarative and procedural knowledge. If teachers want their students to know about and be able to do things in different domains, both declarative and procedural knowledge will have to be taught in the same or each different domain. Learning results in the growth of new structures in the brain. New dendrites and synapses construct elaborate neural networks between neurons. Brain structures do not magically transfer information. Declarative knowledge is grown on different neural networks than procedural knowledge. The following learning principles can help teachers help students: (1) learning is physiological; (2) new brain structures grow with practice; (3) brain structures grow precisely and exclusively for what is practiced: (4) each person has their own unique pattern of brain structures; (5) students need to construct basic networks before they can construct more complex ones; (6) brain structures grow when learners are active; and (7) emotions affect the growth and function of brain structures. Teachers should help students make personal connections to new material and be allowed ample time to practice. (KP)

Acquiring Knowledge and Using It.

Rita Smilkstein, Ph.D.

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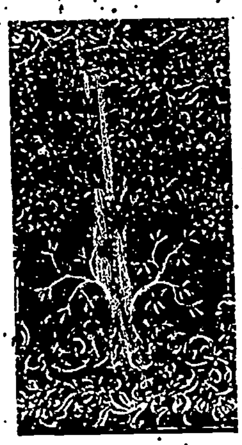
Gamut

Rita Smilkstein

ACQUIRING KNOWLEDGE & USING IT



We teach students something. We expect that once they have learned it, they will be able to use or apply or generalize it in different situations. But students typically seem to have trouble applying what they have learned. This is frustrating and disappointing both for us and for our students.

Why aren't students naturally and easily able to generalize or apply what they have learned in other, different situations or with other, different tasks?

There are a number of questions that are involved: 1) What do we want our students to learn? 2) What is learning? 3) What is teaching? 4) What is involved in generalizing or applying what one has learned?

What Do We Want Our Students to Learn?

The research in educational psychology identifies three major types of knowledge.

One type of knowledge is "rote" knowledge. This is knowledge that is memorized in a given way and that's all the students know about it: They can recite it back but don't necessarily understand what it means and typically can't use it in any thoughtful or creative way. Some rote knowledge, however, might be useful, as when students memorize the multiplication tables.

Another type of knowledge is called "declarative" knowledge. This is knowledge about something (not merely memorized knowledge like rote knowledge). For example, declarative knowledge is knowing or understanding what the book or teacher says. In order to help our students learn about the ideas or information in our lectures and/or texts we might give them reading assignments; we might encourage students to ask questions; we might facilitate class discussion; we might ask students to write about what

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they have read; we might have students give their own opinions about the ideas or information. After we have done this, we might give them a written test so that we can evaluate whether they have indeed acquired this declarative knowledge.

The third type of knowledge is called "procedural" knowledge. This is knowledge of how to do or use or apply a physical and/or intellectual process, method, or skill. For example, being able to perform an experiment, write a paper, or run a piece of equipment is procedural knowledge. Some ways we can help students acquire procedural knowledge is by guiding them as they go step-by-step through a process or through the application of a method. Students need repeated opportunities for independent, authentic practice, that is, for doing the actual activities of the target method, process, or skill itself. After they have done this practice, we might give them a performance test so that we can see whether they have indeed acquired this procedural knowledge.

When declarative and procedural knowledge are separated, students know either about the ideas and information or they know how to do or use or apply a method, process or skill. For example, when declarative and procedural knowledge are separated, students might understand declarative knowledge about the importance of safety in a lab or shop. They might have heard a lecture, seen a demonstration, read a text about the importance of safety. They might have taken and passed a test on this purely declarative knowledge. And, yet, in the lab or shop they seem to have forgotten what they learned or seem unable to apply their declarative knowledge.

Another example is the high degree of declarative knowledge about English grammar that some ESL students have along with a low degree of procedural knowledge of how to use this declarative knowledge in their own writing. They excel at workbook exercises, in drill and practice activities, and on standardized tests about English grammar; yet, their ability to apply that declarative knowledge to their own writing is so low that their writing looks, contrary to fact, as though they have a low degree of declarative knowledge.

This is to be expected: research in educational psychology shows us that knowledge does not automatically or naturally transfer between declarative knowledge and procedural knowledge. Thus, when students don't generalize or apply the declarative knowledge that they have acquired, it is probably because they have not also acquired the related procedural knowledge of how to apply it.

But without the related procedural knowledge, purely declarative knowledge will remain knowledge in words only and not knowledge in action or application.

On the other side of the coin, when students have only procedural knowledge but do not have declarative knowledge, they can do something but they do not necessarily understand what they are doing or why.

What do we, in fact, want our students to learn? Do we want them exclusively to memorize rote knowledge? Do we want them exclusively to learn about something? Do we want them exclusively to learn how to do or use or apply something? Or do we want them to understand what the book and teacher said and also to use our discipline's methods and knowledge in a creative and critical thinking way (declarative plus procedural knowledge)?

For the majority of our students, whatever different things we want them to learn, we have to teach each different thing. If we want them to be able to apply their declarative knowledge, we need to teach them how to apply that declarative knowledge. If we want them to know about—and also be able to do—things in different domains, then we need to teach both declarative knowledge and procedural knowledge about each thing in the same domain or in each different domain.

What Is Learning?

Learning is growing new structures in the brain. This growing is done by the brain itself; it is born knowing how to do it and does it naturally. (Please also see *Gamut* 1990-1991.)

The brain has perhaps 100 billion nerve cells (neurons). Each neuron looks like a plant root with fibers growing off other fibers. Most of these fibers are called dendrites. Over-simplifying the process, we can say that neurons make connections—or communicate—with each other through their dendrites. Each point of communication/connection is called a synapse. Each neuron might have 10,000 synapses with other neurons. All thinking and memory

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is based on this communication between neurons. (As discussed in the 1990-91 *Gamut* article, these physiological brain structures can also be conceptualized as mental schemas or concepts, as knowing.)

When we're born we have all the neurons we'll ever have; but when we learn, we grow new dendrites on the neurons and form new connections between the neurons. Learning, in fact, is nothing other than our brain's growing new dendrites and synapses—and constructing elaborate neural networks between neurons—specifically for whatever we are specifically attending to, specifically experiencing, specifically practicing; in short, our brain tailor-makes new dendrites, synapses, and neural networks for each new specific thing while we are attending to, experiencing or practicing it. These new tailor-made brain structures cannot be used for something else because they were grown and constructed specifically, with exquisite precision, for only the one thing we were attending to and were growing them for. Brain structures don't "magically" transfer. They remain as they were constructed until and unless future learning experiences modify them.

This is why transfer from one thing we've learned to some new and different thing is generally not possible. We learn only what we grow the new dendrites, synapses, and neural networks for. If we want to learn something new and different, then we need to grow new and different tailor-made dendrites, synapses, and neural networks.

Learning new declarative knowledge means we are growing new dendrites, synapses, and neural network for that specific new declarative knowledge. Learning new procedural knowledge means we are growing new dendrites, synapses, and neural networks for that particular new procedural knowledge. Likewise, when we acquire knowledge in different domains, we grow specific and different dendrites, synapses, and neural network for each new thing learned in each different domain.

For this reason, learning must be authentic. That is, as noted above, students need to learn the target knowledge by working on or with that knowledge itself. For instance, when the target knowledge for developmental English students is to write with correct grammar and we teach it by having them doing drill and practice in a workbook or on a computer (electronic workbook), they are growing new dendrites, synapses, and neural networks for doing grammar in

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workbooks but none for the target knowledge of how to use correct grammar in their own writing. To help students learn how to use correct grammar in their own writing, they need authentic practice to learn/grow brain structures for precisely this target knowledge. They need authentic practice for this target knowledge not inauthentic practice with non-target knowledge that students must then "magically" transfer or transform into the target knowledge. Such transfer does not happen.

What Is Teaching?

Teaching is helping students grow new dendrites, synapses, and neural networks.

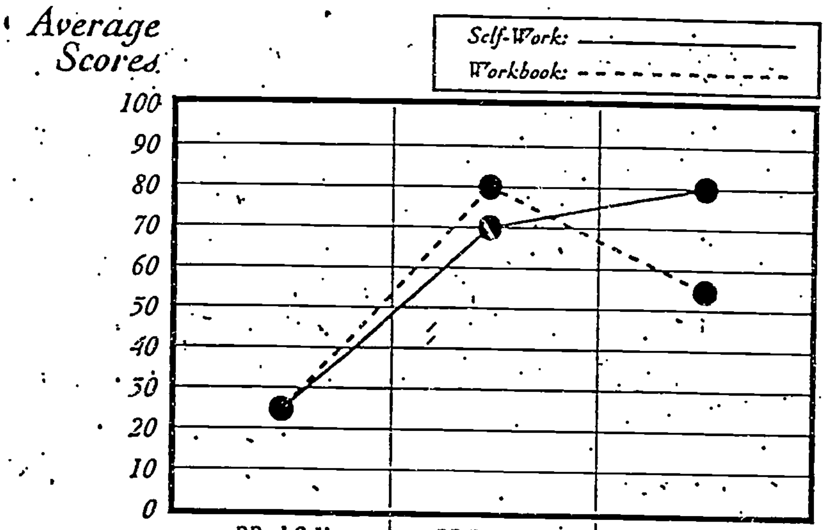
What is involved in generalizing or applying what one has learned?

When the dendrites, synapses, and neural network of each separate thing a student has learned grow enough to make contact with the well-grown neural network of a different thing, an "aha" experience occurs and learners say, "Oh, now I see how they relate." They see this because the two neural networks have made physical contact and now they do, in fact, physically relate. At this moment, learners are finally able to see or grasp that—and how—the different things relate.

The reason this connection occurs, again to over-simplify, is that the dendrites, synapses, and neural networks that during learning experiences have been growing for the different related things—or things that we are trying to lead our students to see as related—become so rich and numerous that the two neural networks are finally able to interconnect. At that point the students can begin to make—and do begin to make—connections that they couldn't have made when there wasn't rich enough dendrite, synapse, and neural network growth for both things to enable their two neural networks to interconnect.

This means that easy and early application, transfer, and generalization do not naturally occur for the majority of students. All students, however, can eventually connect, relate, and synthesize their knowledge of different domains or related knowledge in the same domain—but only after they spend a critical amount of time doing a critical amount of dendrite-synapse-network-growing for each different knowledge about each different thing.

On the other hand, students can usually transfer between tasks and situations that are identical or almost identical, as in electronic or printed workbooks or on worksheets. But is this the kind of transfer that is our goal for our students?



Number of Practice Sentences	PP Post-test (After 1 week)	S-V Post-test (After 2 weeks)
WORKBOOK	158	94
SELF-WORK	33	17

An experiment to test this hypothesis:

To test the hypothesis that neural networks are tailor-made for the specific thing that is practiced, I performed the following experiment.

Experimental Hypothesis:

Developmental English students who learn grammatical elements from a workbook do not transfer or apply, that knowledge automatically to their own writing.

Method: 25 students in a Developmental English class (ENG 094) with an average 6th grade reading level and lack of knowledge of grammatical elements were randomly assigned to two groups (12/13). On a pre-test for ability to identify prepositional phrases (PPs) and subject-verb pairs (SVs) in their own writing, both groups scored low (see graph). For the first week of the experiment, all students were taught together about PPs, a simple element, for 40 minutes of each class. In the last 10 minutes half practiced identifying PPs in a workbook while the other half practiced identifying this element in their own writing. After a week they took a post-test, identifying this element in their own writing. For the next two weeks, all students were taught together about SVs, a very complex element, and practiced in two groups as they had for PPs, followed by a similar post-test.

Results: The workbook group practiced on an average of 158 PPs while the self-work group practiced on an average of only 33 PPs (the writing took more time), for a 5:1 difference. The PP post-test shows the workbook group did better; however, statistically, the amount of this difference is insignificant. For the SV practices the workbook group practiced on an average of 94 SVs while the self-work group had an average of 17; again there was a 5:1 difference. In the post-test, there were three very interesting results: 1) the self-work group did significantly better statistically than the workbook group; 2) the self-work group did better on this more complex topic than they had on the simpler PPs; 3) the workbook group did significantly worse than they had done on the PPs.

Conclusions: 1) It seems that using workbooks not only did not help the workbook group transfer their knowledge of SVs from the workbook to their own writing, but it was actually counterproductive. 2) It seems that even though the self-work group practiced five times less than the workbook group, they learned how to identify the complex SV element in their own writing better than the workbook group. 3) These students learned what they practiced. The group that practiced on their own writing the target task of identifying these elements in their own writing succeeded better than the group that practiced in workbooks, even though the workbook group practiced five times as much.

Learning for Empowerment: Physiological Principles and Their Implications for Teaching

Since synthesizing and generalizing occur when dendrites, synapses, and neural networks grow large and rich enough to interconnect, in order to see how to help our students learn procedural and declarative knowledge and to generalize and synthesize different knowledges, we need to see how to help them grow their neural structures (that is, form mental schemas or concepts).

1. PRINCIPLE: Learning is physiological: new brain structures grow during learning, and learning is the growing of new brain structures. Learning and growing new brain structures are the same thing.

IMPLICATION: Teaching is like gardening; we need to help students grow new organic brain structures.

2. PRINCIPLE: New brain structures grow with practice, i.e., by our making and correcting mistakes and trying again, and usually new brain structures take time—a lot of practice—to grow. (See *Gamut* 1989.)

IMPLICATION: It helps if everyone believes that mistakes are a necessary, inevitable, and important part of learning: we learn by making and correcting our mistakes and trying again. We can say to our students, "That was a good mistake—now you can learn something."

IMPLICATION: It will help if we provide a lot of time for practice. The time spent on authentic practice/feedback is some of the most well-spent class time.

3. PRINCIPLE: Brain structures grow precisely and exclusively for what is practiced: brain structures that grow for one thing are exclusively for only that one thing and do not "magically" change.

IMPLICATION: Students need authentic practice with the target knowledge, so they can grow brain structures for it.

4. PRINCIPLE: Each person has his/her own unique pattern of brain structures because we grow them for everything we experience, and each person has different experiences. Also, new brain structures grow off old ones, i.e., new things must relate to old things.

IMPLICATION: For each new thing we teach, it would help if, as a first step, we find a way to have all students make a personal connection with the new thing so that they can relate the new to what they already know. (See *Gamut* 1990-1991.)

5. PRINCIPLE: Students need to construct basic, foundation brain structures about each new thing before they can construct the dendrite/synapse/neural network—rich, higher structures needed for critical/creative thinking about it, which they will do naturally, as an innate ability—but only after they have first constructed the basic structures. (See *Gamut* 1989.)

IMPLICATION: Expect that students with prior experience in a subject have a brain structure advantage and can start at a higher level than students without this advantage who will need to begin by first constructing the basic structures.

IMPLICATION: A teaching method that focuses on students constructing brain structures from basic to high level, i.e., on students acquiring knowledge from superficial to in-depth, will help. (See the "Natural Teaching Method" in *Gamut* 1990-1991.)

6. PRINCIPLE: Brain structures grow when learners are active. Activity and stimulation prepare the neurons for—and facilitate—new growth.

IMPLICATION: Keeping the activity level as high as possible will help. This three-step cycle works well: students do a task individually (to activate their own brain), then share in small groups of 3-4 (to have active interaction), finally debrief and process as a whole group (to keep activity high as a community). (See *Gamut* 1990-1991.)

7. PRINCIPLE: Emotions affect the growth and functioning of brain structures. (See *Gamut* 1990-1991).

IMPLICATION: It will help if the class/learning environment is positive, supportive, encouraging—with the teacher's full belief in students' desire and innate ability to learn when they have the opportunity to learn the way their brain naturally learns.

8. PRINCIPLE: DNA can affect how quickly brain structures grow for different things, accounting for aptitudes.

IMPLICATION: Expect that some students might have a genetic advantage.

What would be the consequences of following the principles and implications of Learning for Empowerment (see above)?

Would we go more slowly and lecture less in order to provide more time and opportunity for students to thoroughly grow their brain structures through sufficient authentic active in-class participation and practice? Would we need to cover less in a quarter? Would we need to revise our curriculum?

If "magical" transfer doesn't exist, as the research seems to show, then perhaps we need seriously to consider these consequences. ■