Performance-related Feedback: The Hallmark of Efficient Instruction

J. Chem. Educ. MS-2002-0504

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Abstract

Performance-related feedback is feedback connected to some action that suggests to a learner something about the success of their action. Performance-related feedback is a definable and measurable entity. In essentially all cases where one teaching strategy surpasses another in effectiveness, it also is characterized by having more performance-related feedback. This paper makes explicit connections between performance-related feedback and methods of instruction.

Key Words:

Chemical Education Research (CER); Teaching/Learning Aids

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Introduction

This article deals with feedback connected to some action made by a learner. Elsewhere we describe the interactive compensatory model of learning (ICML) and suggest that instruction usually can be described in one of three approaches: direct, socially mediated, and autonomous learning *(1,2)*. All three forms of instruction rely on feedback to varying degrees. We assert that: successful instruction nearly always includes performance-related feedback. From our perspective, improving the quality and quantity of this form of feedback is requisite to improving student learning. Greenwood and colleagues made fine-grained analyses of classroom behaviors, and concluded that some activities enhanced success more than others. Those activities leading to greater success provided learners with "an opportunity to respond"*(3)*. Still earlier work indicated success from controlled practice, academic responding, and feedback *(4)*.

Questioning and responding are classical ways to provide feedback to both student and teacher. One-on-one tutoring is widely held to be the "gold standard" with respect to instruction. Bloom points out that, when compared to conventional small group instruction (typical of classrooms), tutored students perform at a level about 2-standard deviations higher *(5)*. We interpret the success of tutoring in terms of feedback.

Because of their interest in developing automatic tutoring systems, Graesser and colleagues have studied tutoring in some detail *(6)*. With respect to questions asked in an undergraduate course in research methods, the average number of student questions asked per hour of conventional instruction was 3.0. This compares with tutoring sessions of

comparable length, wherein students ask 21.1 questions and tutors ask 117.2 questions on the average. Clearly, best instruction provides learners with much more feedback through questioning and responding than does conventional instruction.

Evidence that infants and young children learn language from feedback is especially strong *(7,8)*. Computers successfully model human development with respect to language learning *(9)*. To teach a computer, one gives it performance-related feedback. It may take 20,000 feedback sessions to observe behavior from a computer that 5 or 6 sessions will bring about in a 2-year old child. These days, however, 20,000 feedback instances can be provided to a computer in seconds.

Examples of learning and efficiency gains from instruction focused strictly on performance related feedback are available from many seemingly diverse areas. Using just exposure to examples followed quickly by feedback, Kellman has observed some striking improvements in learning to perceive and classify patterns. Training times for reading dial displays in airplane cockpits are greatly reduced *(10)*. In describing this work, the authors state: "…Discovery in the learning of structure is a process of filtering which of the possible details, patterns, and relationships are relevant to a particular task or goal. … This learning process advances when the subject makes rapid classifications and receives feedback (emphasis added) over many short trials…" Performance in detecting molecular geometries is greatly enhanced using this strategy *(11)*. Chapman reported remarkable gains in teaching introductory organic chemistry students how to determine molecular structures from nmr spectra when the strategy was employed *(12)*.

Our position is that performance related feedback counts most in successful instruction. Increasing student learning by improving instruction involves examining the

quality and quantity of this critical entity. Here we analyze methods of instruction, and indicate how each provides feedback.

Performance-related Feedback

Falling off while learning to bike, or sensory observation when a prediction about the world goes awry (as in viewing a discrepant event) both provide a general form of feedback. Contrastingly, performance-related feedback might involve looking at an answer key immediately after an exam, or hearing a lecturer present a brief explanation after an in-class question activity. The distinguishing factor is the link between the student's action (taking a test or asking a question) and the response. It is possible to make extensive use of performance-related feedback in researchable settings, even to the degree of providing feedback to vicarious performances – situations in which the learner responds to him/herself, but in which there is no measurable, verifiable observable behavior upon which to base feedback.

Testing; Practice

In the world of classrooms, nothing gives performance-related feedback better than testing. Frequent testing is valuable. Testing does not have to imply a terminal, grade determining judgment activity, however. Testing can be used as a guide for providing just-in-time highly targeted feedback. Frequent testing is at the heart of the Keller Plan: a self-study system where students demonstrate mastery by passing a series of repeatable exams. We have long argued for repeatable testing *(13).* We ascribe the success of Keller Plan or PSI strategies as rooted in their repeatable testing. Unlike other strategies, the effects of Keller Plan courses often can be seen two or three semesters after the course ends *(14-16).*

Dynamic assessment is a strategy for providing feedback to an examinee within a testing situation. Students learn the accuracy of each response and the examiner provides remediation as the exam is given. For example, the instructor would correct student completed reaction mechanisms between student attempts. Swanson concludes that dynamic assessment leads to improved testing performance as compared with 'static' assessment *(17)*.

Some teachers replaced the term testing with the term practice, and offer opportunities for practice beyond mastery. The results of such instruction are impressive, reminiscent of those obtained in Keller Plan courses *(18)*.

In Class Pair Discussion

Having lecture room students work in pairs for 120-180 seconds to formulate and discuss a response to a teacher-presented question, after which time all pairs vote and the teacher gives and discusses the accepted answer, if any, provides substantial opportunity for learning *(19)*. During the discussion, both members of the pair can perform and evaluate each other's performances. Having the lecturer provide a summation gives still more feedback. This strategy can require processing that is much deeper than, say, just taking notes. We recommend that lecturers following this approach include at least some of the items discussed on tests that count. So, if a lecturer uses the strategy, say, 5-7 times each week, using 1-2 items from a major test given every three or four weeks will increase attention given to these questions.

Cooperative Learning

Cooperative learning, once much more widely advocated than it is today, involves students working in small groups. Within these groups, learners engage in activities

where they provide feedback for one another about their work. The current Peer-Lead Team learning model is a recent example *(20)*. Research results suggest that using this strategy improves learning by ~0.5 standard deviations *(21)*. It is quite clear than any results of cooperative learning can be interpreted in terms of performance-related feedback. In best case examples, such as those of Brown *(22)*, the nature of the peer-to-peer feedback is very well defined and controlled. Strategies such as training students to focus their comments on connecting main ideas, or describing their thinking during problem solving can have

Computer Assisted Instruction

Autonomous learning can consist of reading a textbook. It also might include using computer-assisted instruction (CAI). Not all computer-assisted instruction is the same. Some consists of electronic page turning, often by visiting web pages. The most effective CAI consists of having students respond to problems and receive feedback about those responses. Garbin *(23)* has documented that, when appropriate opportunities for practice are provided, most students can succeed at very high levels of performance. He uses mastery strategies that diminish the variance in the large 'prior knowledge" component described in the ICML *(1)* by engaging students in unlimited opportunities for learning important course terminology in a low-stakes computer testing system. Garbin conjectures his student's failure in problem solving has more to do with interpreting terminology than applying procedures. Thus, the feedback provided by the system allows students to compensate for poor prior knowledge by engaging in an iterative expert feedback loop.

Inquiry versus Guided Inquiry; Scaffolding

Inquiry is a difficult business. To make inquiry work in real teaching settings, a strategy called guided inquiry (guided design) is employed *(24)*. Guided inquiries provide structure. Cognitive scaffolding is a construct that describes tools (often people) that act as guides for a student. These scaffolding tools provide both information and support for intellectual development. In the instructional program cited, "critical thinking questions" are employed, and instructors move from group to group. "This provides an opportunity for feedback to the group and for catching any confusion or misunderstanding that may have been missed during class. Occasionally a question may be posed to one of the group members to make sure that he or she understands a concept or to elicit a verbal explanation of an answer which may be correct." Simply, scaffolding can be accomplished by introducing sub-steps with appropriate feedback to help elicit a path.

Related Issues

Matching Learners with Feedback

Feedback must be given in a useful form. For example, giving adult speakers of Japanese ordinary feedback about English "r" and "l" sounds has proven useless. A good cognitive model is the foundation for providing feedback in a useful form. The critical cognitive variable for predicting the success of current learning is prior learning *(1)*. Good tutors become very adept at managing cognitive variables and providing useful feedback. Computer generated feedback, while potentially copious in quantity, lacks cognitive matching. In the absence of a good cognitive model for delivering feedback, computers are inefficient at best.

Successful feedback is provided in digestible quantities. Researchers describe these quantities in terms of cognitive load. Many experiments suggest that our ability to process information is a function of available working memory. In working memory, we can keep track of about five items or chunks at a time. Because the size of a chunk can grow with learning and experience, the complexity of the tasks we can undertake successfully also can grow *(25)*. Cognitive load is a measure of how much a task utilizes working memory. Consider, for example, the load required for interpreting molecular geometry from a chemical formula as opposed to a structural formula. While both may be appropriate, the lower cognitive load required by the structural formula makes it a better choice for feedback to novices. Johnstone has discussed the cognitive load concept as it applies in chemistry education *(26)*. Further, cognitive load has been the basis of analysis in the very large strategy comparison literature developed largely by Sweller and his students *(27)*.

Lecture; Lecture Notes

In college science courses, we lecture. In many high school chemistry courses, we lecture. Lecturing is where we can model, and modeling has great value. Those readers having the opportunity to hear lectures from Linus Pauling or Henry Eyring or Gilbert Stork, for example, have experienced what it means to listen to a great chemical thinker think out loud, and to learn from this experience. Lecturing is an instructional strategy wherein performance-related feedback is minimal. While perhaps better than no notes in a situation where the teacher lectures, most of the feedback that comes from creating notes is internal – a combination of tactile and visual feedback; there is no external evaluation of the performance.

Self-explanation is a useful strategy for providing internal feedback *(28)*. It is possible that a learner attending a lecture experiences self-explanation, and this is effective in learning. Self-explanation is not automatic; students become more successful with this strategy after both explicit instruction about the strategy and feedback about their success in the early stages of using the strategy. In a study related to teaching LISP programming, Brown showed that explicit instruction in self-explanation led to large improvements in learning *(22)*.

Projects; Research

You would be correct in your suspicion that the authors believe that teaching via projects and research is inefficient. The world does not come to us neatly bundled and labeled with readily understood rules. If we stumble along as we try to improve ourselves as chemistry teachers, why shouldn't we have our students stumble along, too? Engaging students in projects and research almost certainly is inefficient, but at the same time it is the truest measure of what we do as scientists.

Schools are about preparing people for other life events. There is a perspective that is very important to keep in mind. Engaging students in activities that more closely mimic authentic activities is not always the most efficient way to prepare students. A recent quantitative and qualitative meta-analysis on teaching science problem solving *(29)* draws several conclusions from 40 experiments in 22 reported studies. Especially effective were immediate feedback to learners as well as explicit external guidelines and criteria. Signal among the conclusions is the following:

"It was found that the cognitive activities involved in successful interventions do not have to coincide with those of the goal task of science problem solving. Studying worked

examples or concept mapping may also contribute to the mastery of science problem solving. The important aspect of these activities is that they stimulate the development of the knowledge base and thinking skills."

We suggest that a "some research curriculum" is good, but that an "all research curriculum" is both unnecessary and inefficient.

Summary

Successful instruction nearly always includes performance-related feedback. The intent of this article has been to present this notion explicitly, and to describe the many ways in which a chemistry teacher can provide students with performance-related feedback. Experienced teachers appreciate many ways in which they can help their students to learn. By considering feedback explicitly when designing instruction, the task of selecting strategies becomes focused and goal-oriented. You might say, 'I'll give a test here' or 'I'll ask small groups to discuss this there' because those will be the best ways to provide feedback. Your instructional goals can be measured partially in terms of the feedback you provide. While expensive and often cumbersome, testing has the advantage of providing both you and your students with direct feedback about what has been learned. Having students briefly discuss a topic in class, vote in some demonstrable way (like a show of hands), and then learn about their choice also is effective in providing feedback. But running a course in which the only feedback for students is a monthly examination, one returned weeks after it is written, is a minimal form of feedback and is best avoided.

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