Suggesting that the research cited earlier indicates that we should make textbooks and lectures more incoherent is clearly an overstatement. On the other hand, some middle ground is worthy of investigation. Perhaps clarity and coherence is most efficient at helping learners achieve some core knowledge, but after reaching some threshold knowledge it may serve the learner better to rely less on instruction and more on her/his own mental efforts to make sense and distill the knowledge into a form useful for future use.

Background

The workshop was organized around the following three themes:

1. **Context dependence of transfer**. The acquisition of knowledge or a skill does not ensure that the knowledge or skill will be appropriately (or inappropriately) applied to relevant situations. What do we need to know about the contexts of learning or application of learning in order to facilitate transfer?

2. **Conditions for transfer**. What are the conditions that affect the appropriate (or inappropriate) application of knowledge or skill. What do we need to know about the contexts of learning, or application of learning, in order to facilitate transfer?

3. **Metacognitive issues for transfer.** Metacognitive research indicates that a significant part of effective learning is to be aware of, and in control of, one's own learning. What research base is needed to promote reflective learning? What are the implications for classroom practice?

Workshop participants were divided into three groups, with each group working on one of the themes above. Participants were given the governing charge for the workshop at the opening plenary, namely that by the end of the workshop, each group should have formed answers to three organizing questions for each of the three themes: 1) What are the primary issues?, 2) What is the research knowledge base? (What do we know?) and 3) What do we need to find out? (How can we learn more?) A chair and a co-chair were named for each group to keep the group on task and to capture the consensus of the discussions. More details concerning the agenda and charge are provided in the Appendix.

Outcome of Workshop: Research Agenda

The three sub-sections below are the reports from the co-chairs of the breakout groups that discussed the three themes outlined in the previous section. The three reports are included here in largely the same form as they were submitted, and hence the format and style of each is unique. To have "sanitized" each report into a consistent format would have not captured the unique flavor of what transpired in each group. It is interesting to note common threads running across the three reports below, such as whether or not current assessment practices are structured to measure, or even promote, far transfer, and how instruction might be structured to promote far transfer as opposed to doing well on mandated tests.

Context dependence of transfer

There are two contexts to consider: The context of original learning and the context of the transfer problem.

Context includes those things that are formally relevant to the core concepts being taught in the learning situation and which are supposed to be applied in the transfer situation. But context also includes many things that, while not formally relevant, may strongly influence learning as well as the likelihood that the learning will be recalled and used in transfer.

These additional context factors include the learner's prior knowledge, the learner's expectations about the purpose of the original learning, the teacher's expectations of the learner, the learner's internal states during learning and transfer, group versus individual learning in relation to group versus individual application of knowledge, as well as the physical environments of the learning and transfer situations.

Context can be important as a basis for cueing recall of the original learning or it can interfere with recall.

- A central question of transfer is: What remains invariant from the learning context to the transfer context? How can the learner best be taught this invariance?

- What are the cues and strategies that can be used to trigger appropriate knowledge to be applied in a particular situation? This question recognizes that the learner often has the relevant knowledge in a transfer situation but fails to make use of that knowledge.

- How important are the learner's expectations during original learning and transfer? How important is it that the learner believe he/she will actually need the knowledge in "real life" as compared to just being able to pass an exam? Does the learner actually need to have the expectation that he/she is learning something? This is relevant to the use of informal learning situations such as educational television and computer games.

The research questions generated by the context group are:

1. How can education prepare people to recognize the cues that signal application of appropriate knowledge? What are the cues that produce or inhibit application of appropriate knowledge?

2. When is instruction for near transfer most appropriate as compared to instruction for far transfer? Are these dissociable? Does one type of learning hinder the other? In specialized training, such as for operating a nuclear power plant, should the learning situation always be an exact copy of the transfer situation? Should training emphasize near transfer at the expense of far transfer? If so, will the learner be able to think analytically if emergency situations arise that do not replicate the training context?

3. How does context affect deep understanding and preparation for learning as opposed to influencing whether relevant knowledge is retrieved?

4. When should tests match the learning context?

5. Will teaching for far transfer influence performance on traditional educational assessment? There were arguments for both enhancing and diminishing effects.

6. How does assessment of varying kinds influence teacher practice and student performance with respect to near and far transfer?

7. What do employers of various types want with respect to near and far transfer? To what extent do they want employees with narrowly defined skills as compared to broad abilities to solve problems and learn new skills?

8. What are the contextual factors (especially socio-cultural factors) that shape attitudes when entering new contexts that could involve transfer?

9. Is transfer hindered by compartmentalization of instruction? How integrated should instruction be?

Conditions that Facilitate Transfer

Cognitive research has converged on the conclusion that transfer is better if people have learned initially in a way that fosters deep, abstract understanding of central principles of a field, rather than emphasizing the rote application of rules triggered by surface similarities among problems. One method for achieving such deep, abstract understanding is to involve students in multiple examples illustrating a central principle drawn from an equivalence class where the surface characteristics of problems vary as widely as possible. It should be emphasized, however, that drawing this conclusion does not entail saying that automatization of skills and of facts is not relevant to transfer. On the contrary, research in areas such as reading and early mathematical development suggests that both conceptual learning and automatization (e.g. of decoding skills for reading, of number facts for early mathematics) are important.

It is also clear that evaluating transfer requires clear delineation of the nature of mature competence as well as, preferably, knowledge of the sequence of states that typically leads to mature competence. However, we know relatively little about these issues in many domains. Thus, there is a **research need** to characterize such sequences and to determine if some errors or failures to transfer are potentially productive errors of growth or expectable restrictions on generalization, whereas other errors or failures to transfer indicate that the learner has encountered a significant barrier to continued growth. Representational requirements to facilitate deep understanding also need to be better characterized: both internal mental representations and external representations (e.g., maps, systems of notation, etc.).

Learning for understanding may be more compatible with the implicit or explicit learning goals of some communities of learners than of others. There is a **research need** to consider whether there are barriers to such learning and teaching in the perceived needs of some learners to learn material of immediate practical relevance. If there is, there is obviously a further need to consider in detail how to work with learners with these assumptions.

Implications for Education and Assessment

If we accept that cognitive research suggests the value of certain instructional strategies and goals, there are important implications for educational practice and for assessment that require further research.

1. Taking interventions based on these insights to scale may be quite difficult, as is true for many new educational programs. NSF is currently funding projects through IERI that involve the scaling problem, but there should also be consideration of funding projects to explicitly compare different techniques of scaling up.

2. One vital aspect of the scaling problem is what points of influence are available. Practicing teachers are often the target, but it can be hard to reach them. Pre-service teachers are one additional audience that can pay long-term dividends. School psychologists could be an entry point. In all these cases, the aim of researchers should go beyond discussion of a particular program or curriculum. It should be to foster learning of a deep, conceptual kind about the learning process. With such understanding, teachers and other professionals will be equipped to make good on-line decisions about such issues as, for example, how much students should struggle with new material, when research suggests there should be some struggle but not too much.

3. There is increasing concern about "teaching to the test" in an era when there is much demand for accountability. We need to devise tests that assess broad transfer so that accountability does not end up fostering teaching that will not support transfer. Science tests are in special need for attention. Technology can aid in the project of devising assessments that look at deep conceptual change. Assessments focused on preparedness for future learning (e.g., solving a relatively complex novel problem) may be more revealing of transfer than those focused strictly on analogous problems across isolated domains.

4. Many participants believe that "teaching to the test" may actually be self defeating, resulting in lower performance than teaching in a way that supports broad transfer. Research to evaluate the hunch that teaching for understanding may improve scores even on fairly traditional assessments should be supported.

Metacognitive Issues for Transfer

Primary Issues

Research on transfer has emerged from two distinct traditions: associationist-learning and cognitive approaches (the latter including Gestalt psychology). Definitions, and empirical examples, of transfer reflect these intellectual roots. For example, stimulus generalization grew out of the associationist-learning tradition, whereas contemporary studies of analogical transfer reflect a cognitive approach. The classic transposition effects, studied extensively in rats and humans, were explained from both perspectives. Although metacognition is the most recent addition to the research landscape, it is a natural continuation of the cognitive tradition emphasizing "mentalism."

Transfer can be defined as the cognitive benefits derived from prior learning or problem solving that accrue to problems that are not identical to studied exemplars. Issues that emerge from such a definition include distinguishing learning from transfer, near from far transfer, the peculiar role of negative as opposed to positive transfer, and interactions with consciousness, strategies for learning and problem solving, and retention of information across study and transfer episodes. The latter interactions between transfer per se and its active application by learners and problem solvers involve metacognition.

Scientists attending the Transfer Workshop agreed that metacognition refers to any cognitive act about cognition, but they differed in their emphasis on the centrality of consciousness (explicit awareness of cognitions about cognition); verbalization (whether learners or problem solvers can articulate their metacognition); strategies (e.g., practical intelligence about effective tools and techniques); insight about quality (whether metacognition involves an evaluative or critical stance toward mental processes); or insight about self (a way of thinking that involves self-assessment, rather than merely skill-assessment). Issues of definition connect inexorably to those of measurement. For example, if verbalization and consciousness are not essential elements of metacognition, then measures that rely on verbal reports may underestimate this ability. Regardless of whether these elements must be strictly included in a definition, attendees concluded that these are important, researchable dimensions of metacognitive transfer.

Scientists also identified several timely issues of national significance. Although these issues are only enumerated in this section, they are discussed in more detail in the sections that follow. Foremost among these is the issue of assessment, which has taken on increased significance because of recent national legislation. Another key issue that emerged was socio-cultural context, and contextual factors generally. These included identification of the kinds of learning required to adequately prepare the workforce in a fast-moving, knowledge-based economy (e.g., generalized problem solving, more narrow specific skills, or both). Participants cautioned against assuming that lower-paying jobs do not require substantial transfer and metacognitive awareness, but they acknowledged that some jobs appear to require near transfer and automaticity (e.g., piloting a plane, which might best be taught through highly realistic flight simulation). The group underlined the importance of focusing on skills that transfer from school to work, from home to school, and from one cultural context to another, without foreclosing educational and job opportunities for students by narrowing or lowering the quality of the curriculum. Finally, advancements in technology continue to make available many new options to enhance learning, transfer, and assessment. However, scientists stressed that most of these technological advances find their way into classrooms and work contexts without a solid foundation of research about their effectiveness for learning and transfer.

Background of Prior Research

Despite research in the learning tradition, which does not mandate understanding to explain near and far transfer, attendees agreed that research demonstrates that teaching for understanding produces more robust transfer. Thus, although transfer can occur without a pedagogical priority on understanding, rote learning is less effective than teaching for understanding in promoting transfer. In addition, instruction of the same underlying concept in multiple contexts facilitates transfer. (The precise relation among those contexts that optimally facilitates transfer is uncertain.) Research on direct instruction in critical thinking skills, ranging from deductive inference to statistical thinking (e.g., applying sample size in judging evidence quality), has produced reliable results. Much of this

instruction emphasizes metacognitive awareness. Little is known, however, about cross-domain transfer (e.g., critical thinking in English courses transferring to Biology), and some research on analogical reasoning suggests that such transfer is difficult.

Assessment or testing has the potential to enhance metacognitive awareness, dispelling illusions of knowing and providing feedback about areas of weakness. Prior research on the psychometric properties of different tests must be brought to bear on the issue of their usefulness as a pedagogical tool. For example, tests that lack validity and reliability are unlikely to produce useful feedback to learners, teachers, or other decision makers. Moreover, tests differ in what they measure, some aiming at specific content knowledge and procedural skills, whereas others tap more general knowledge and skills. Distinctions in the research literature between rote versus conceptual understanding, concrete versus abstract knowledge, declarative versus semantic knowledge, verbatim versus gist representations, as well as task analyses of the cognitive processes involved in deep understanding of, say, physics or mathematics, may help to clarify the conditions under which "teaching to the test" could be beneficial.

Given a valid and reliable test of some knowledge or skill worth assessing, the question arises as to whether teaching directly to the test or teaching for transfer produces better performance. If teaching for transfer raises metacognitive awareness, then the latter might mediate improved performance. Prior research on metacognitive awareness, such as judgments of the quality of one's own learning, indicates that metacognitive judgments are generally abysmal in the absence of formal instruction. Indeed, naïve intuitions about the quality of one's learning or the effectiveness of strategies for learning are often precisely the opposite of what has been shown to be true through empirical research.

Closely allied with prior work on assessment, research on individual differences has identified stable personality traits and motivational factors that should affect learning, transfer, and metacognition. Promising connections between such factors (e.g., need for cognition) and transfer or metacognition have not been explored in any depth. Expertise is another dimension on which individuals differ, and this area of research can be plumbed for insights about the organization of knowledge and how development does or does not progress toward adaptive thinking, depending on one's theoretical perspective. Notably, cognitive consistency (transfer across superficially different situations that tap the same cognitive competence) has been treated as an essential element of rationality in theories of judgment and decision-making. An emerging theme of the latter research is that of task variability, namely, that the same individual can exhibit bona fide competence in one context, and yet fail to apply that same competence in an equally relevant, but different, context.

Finally, participants pointed out that memory has been a highly active area of research, but most of this work has occurred since transfer was intensively studied by learning or Gestalt theorists. In particular, research suggests that representation and retrieval are relevant to explaining and predicting transfer. The data suggest that learners who transfer have different mental representations of problem information, compared to those who do not. In addition, cues in the problem or environment govern retrieval of prior learning, and, hence, the likelihood of transfer. Many of the conundra of earlier theorists, it was argued, could be explained by recourse to these newer ideas.

Key Questions for Future Research

Three main themes emerged from the discussion of transfer and metacognition. These themes are ones that build most efficiently on the foundation of prior research, and yet speak to timely issues of national significance. First, there is a need to explore habits of mind that produce better transfer across domains. Scientists' best judgment at this time is that an attitude of active inquiry, insight that seemingly disparate contexts can involve similar kinds of thinking, and an evaluative stance towards one's own cognition enhance transfer. However, they raised the possibility that better metacognition might be unrelated to better cognition. The importance of situated metacognition (and, conversely, contextual transfer) was another pervasive theme. Research should be directed toward blending laboratory-based and real-world observations (i.e., twinning or close coordination of carefully constructed studies across domains).

Finally, scientists agreed that there was an overarching need for theory-driven research. Many of the open questions and practical problems that had been discussed could be addressed through a greater emphasis on processes and mechanisms underlying transfer or metacognition. Accurate assessment, for example, hinges on a sound analysis of such processes and mechanisms. Three areas seem especially promising for scientifically rigorous theory development:

1. Representation and retrieval

2. Domain specificity versus generality

3. Adaptive metacognition

These choices reflect the groups' judgment of enabling prior research (e.g., in memory), important questions (e.g., transfer across home, school, and work environments), and key conceptual challenges (e.g., determining whether metacognition is adaptive).

Additional Recommendations

The participants noted that inter-disciplinary collaboration is beneficial to research about scientific and mathematical learning, and that research conferences can facilitate that kind of collaboration. However, they pointed out that there was a need to encourage better communication about research within disciplines, and that this has received virtually no attention or support. This need is heightened by the growing expansion of research knowledge. Areas of cross-fertilization that would be germane for the study of transfer and metacognition include:

- Developmental and adult cognitive scientists

- Applied and basic scientists working on similar topics

It would be essential to continue to include content specialists (scientists and mathematicians) in such conferences. Although some content specialists might be naïve about cognitive components of problem solving (and would benefit from concepts, measures, and data generated by cognitive psychologists), cognitive psychologists who lack sufficient content knowledge are liable to construct naive theories about scientific or mathematical understanding.

Concluding Remarks

The research agenda that resulted from this workshop is clearly not "*the*" research agenda for transfer of knowledge but rather "*a*" research agenda. The research agenda presented here, however, reflects the views and consensus of the workshop attendees. By design, this was an invitational workshop and the group invited to attend was small, albeit comprised of individuals with rather impressive credentials. It was never the intention of the organizers to assemble a "complete" group representing all relevant fields and views related to transfer. Thus, the agenda presented may contain holes that will need to be filled out at some future date.

Acknowledgement & Dedication

This report is dedicated to the memory of Rodney R. Cocking, who suffered a tragic death a month prior to the workshop. Rodney was instrumental in planning the workshop, and he had great ambitions for it. As Program Director for the Developmental and Learning Sciences Program at NSF, Rodney was devoted to strengthening the connections between basic research on cognition and educational practice. His tireless efforts made the workshop possible, and his influence was noticeable throughout. Rodney was a dear friend and colleague of most who participated. It is our hope that we have come close to delivering on his vision.