DOCUMENT SUMMARY This 1988 paper by John Sweller introduces the core principles of what would become **Cognitive Load Theory**. The central argument is that conventional problem-solving, particularly using a **means-ends analysis** strategy, is an inefficient and often ineffective method for learning and acquiring expert **schemas**. Sweller proposes that this type of problem-solving imposes a heavy **cognitive load**, consuming limited working memory resources that are then unavailable for the processes of **schema acquisition**. The paper supports this claim with experimental evidence and a computational model, concluding that instructional methods that reduce this extraneous load, such as using worked examples or goal-free problems, are superior for facilitating learning.

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METADATA Category: CLINICAL Type: report Relevance: Core Update Frequency: Static Tags: #cognitive_load #cognitive_load_theory #learning #instructional_design #problem_solving #means_ends_analysis #schema_acquisition #worked_examples #educational_psychology Related Docs: This foundational theory paper should be linked with any content on psychoeducation, skill-building for clients, and effective teaching strategies. It provides a strong theoretical basis for using guided, structured learning over unguided "discovery" methods. Supedeses: N/A

FORMATTED CONTENT

ABSTRACT

Considerable evidence indicates that domain specific knowledge in the form of **schemas** is the primary factor distinguishing experts from novices in problem-solving skill. Evidence that conventional problem-solving activity is not effective in **schema acquisition** is also accumulating. It is suggested that a major reason for the ineffectiveness of problem solving as a learning device, is that the cognitive processes required by the two activities overlap insufficiently, and that conventional problem solving in the form of **means-ends analysis** requires a relatively large amount of cognitive processing capacity which is consequently unavailable for **schema acquisition**. A computational model and experimental evidence provide support for this contention. Theoretical and practical implications are discussed.

THE DISTINCTION BETWEEN EXPERTS AND NOVICES

Extensive research indicates that the major factor distinguishing expert problem-solvers from novices is the possession of domain-specific knowledge in the form of

schemas. A

schema is a cognitive structure that allows a problem-solver to recognize a problem as belonging to a particular category that requires particular moves for a solution.

This distinction is evident in three key areas:

1. **Memory of Problem States:** Experts can recall realistic problem configurations (e.g., chess positions, circuit diagrams) far better than novices, not because of superior short-

term memory, but because they can group information into larger, meaningful chunks using their schemas.

2. **Problem-Solving Strategies:** Novices tend to use a general-purpose problem-solving strategy called **means-ends analysis**. This involves working backward from the goal, setting subgoals to reduce the difference between the current state and the goal state. Experts, possessing the relevant **schemas**, work forward from the givens, as their schemas immediately suggest the appropriate solution steps.
3. **Problem Categorization:** Novices tend to categorize problems based on surface features (e.g., putting all problems with an "inclined plane" together). Experts categorize problems based on their deep structure and the underlying principles needed for a solution (e.g., putting all problems solvable by "conservation of energy" together), which is guided by their schemas.

THE PROBLEM WITH LEARNING THROUGH CONVENTIONAL PROBLEM-SOLVING

While it is commonly assumed that extensive practice solving conventional problems is the best way to gain skill, there is reason to doubt this assumption. The goal-directed search required by conventional problem-solving can interfere with learning the problem's essential structure. Experiments using puzzle problems and maze problems found that subjects focused on reaching a specific goal often failed to learn the underlying rules or structural features of the problem, whereas subjects given non-specific goals (e.g., "find the route to the goal" without knowing the goal's location) learned these characteristics rapidly.

WHY MEANS-ENDS ANALYSIS INTERFERES WITH LEARNING

There are two primary, related mechanisms by which **means-ends analysis** interferes with **schema acquisition**:

1. **Selective Attention:** To solve a problem using **means-ends analysis**, a person must focus their attention on reducing the difference between the current state and the goal state. This process does not require attention to the relationships between problem states and the moves that link them, which is precisely the information needed to build a **schema**.
2. **Limited Cognitive Processing Capacity (Cognitive Load): Means-ends analysis** imposes a heavy **cognitive load** because the problem-solver must simultaneously consider and mentally manipulate multiple elements: the current state, the goal state, the difference between them, the relevant problem-solving operators, and a potential stack of subgoals. This complex process can consume so much cognitive processing capacity that there are few resources left over for **schema acquisition**, even if the problem is successfully solved.

> Goal attainment and
>
> **schema acquisition** may be two largely unrelated and even incompatible processes. The cognitive effort expended during conventional problem solving leads to the problem goal, not to learning.

A COMPUTATIONAL MODEL OF COGNITIVE LOAD

To objectively measure the cognitive load imposed by different strategies, a computational model was built using a production system language (PRISM). The model was designed to solve equation-chaining problems (common in physics and geometry) using either a

means-ends analysis strategy (when a specific goal was provided) or a nonspecific goal, forward-working strategy.

The results of the simulation provided strong evidence that

means-ends analysis imposes a significantly higher **cognitive load**. When solving the same 3-step problem, the means-ends strategy required:

- More information to be held in working memory (peak of 16 items vs. 14)
- More active productions (rules) to be considered (4 vs. 1)
- More cycles to reach a solution (5 vs. 3)
- More total conditions to be matched during the process (29 vs. 17)

The greater number of active productions and decisions required by the means-ends strategy (e.g., should I set a subgoal? which subgoal track should I follow? can a subgoal be calculated now?) is cognitively demanding and these processes are not related to

schema acquisition. In contrast, the nonspecific goal strategy requires only one decision: can a value be found for any unknown?. This simpler process imposes a lower cognitive load, freeing up resources for learning.

EXPERIMENTAL EVIDENCE FOR COGNITIVE LOAD EFFECTS

Experimental data supports the idea that the high cognitive load from **means-ends analysis** impairs performance on other cognitive tasks, including learning.

- **Increased Mathematical Errors:** In a study by Owen and Sweller (1985), students solving conventional trigonometry problems with specific goals made four to six times as many mathematical errors as a group solving nonspecific goal problems. This suggests the cognitive overload from the means-ends strategy left fewer resources available for the correct application of mathematical rules.
- **Dual-Task Interference:** A new experiment was conducted where problem-solving was the primary task and memorizing the problem's givens and solution was a secondary task.
    - One group solved conventional problems (high cognitive load).
    - Another group solved nonspecific goal problems (low cognitive load).
    - **Result:** The group solving conventional problems made significantly more errors on the secondary memory task. They showed poorer recall of the problem's structural features (angle positions, side positions) and its solution. This provides direct evidence that the high
    cognitive load imposed by conventional problem-solving interferes with performance on a secondary learning task.

THEORETICAL AND PRACTICAL IMPLICATIONS

The findings have significant implications for both learning theory and educational practice.

- **Theoretical:** Learning theories that assume learning is a direct consequence of problem-solving (e.g., Anderson, 1982) may need modification. The evidence suggests that goal attainment (**problem-solving**) and **schema acquisition** (**learning**) can be incompatible processes.
- **Practical:** The heavy emphasis on conventional problem-solving in mathematics and science curricula is likely an inefficient learning device. To facilitate **schema acquisition**, conventional problems that induce a heavy cognitive load should be replaced with instructional materials that reduce this load, such as **worked examples** or nonspecific goal problems. The use of conventional problems should be reserved for testing or as a motivational tool.

CONCLUSIONS

1. Conventional problem-solving through **means-ends analysis** imposes a heavy **cognitive load**.
2. The cognitive mechanisms required for problem-solving are substantially distinct from those required for **schema acquisition**.
3. The cognitive effort required by conventional problem-solving may therefore interfere with, rather than assist, **schema acquisition**.
4. Since **schema acquisition** is the most important component of expertise, an over-emphasis on conventional problem-solving may actually retard the development of expertise.
5. Current theories and educational practices that assume problem-solving is an effective means of learning may require modification.