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Effects Inquiry Learning and Direct Instruction on Conceptual Understanding Using Piagetian and Information Processing Approaches

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Abstract

This study explores relationships between developmental theories, teaching methods, and students' conceptual understanding of torque, a physics concept. The research compares direct instruction, rooted in information processing theory, with inquiry-based learning, rooted in Piagetian theory, examining their effects on four types of conceptual understanding. A total of 206 college students participated in one of four torque lessons, each paralleling externally-valid learning situations: direct instruction, free discovery, scaffolding, and like an inquiry-based classroom. All lessons used the Piagetian balance beam task, with examples in direct instruction matching scaffolds in the scaffolding and inquiry conditions. Following instruction, students completed a test with four types of items assessing base problems, situation transfer, mathematical transfer, and conceptual lures. Results showed direct instruction outperformed free discovery and scaffolding on base problems, situation transfer, and mathematical transfer, supporting information processing accounts. However, the inquiry-based classroom lesson performed similarly to direct instruction. Moreover, on conceptual lures, inquiry-based classroom and scaffolding conditions outperformed direct instruction, aligning with Piagetian accounts. While direct instruction is effective and time-efficient, the extra time and effort of inquiry learning is especially beneficial when educators aim for their students to acquire the deepest forms of conceptual understanding.

Effects Inquiry Learning and Direct Instruction on Conceptual Understanding

Using Piagetian and Information Processing Approaches

Do children develop through passive receipt of experience or do they actively construct their own development? This central theoretical question of developmental psychology shapes a prominent practical debate about how two broad teaching methods promote effective learning and interest in a subject. Through inquiry learning students construct their own knowledge of subject matter while being guided and assisted by the teacher. Through direct instruction, teachers communicate subject matter through lecture. Piaget's constructivist account provides a theoretical foundation for inquiry learning. Piaget (1969) believed to foster science learning schools should develop "methods of teaching … that emphasize the importance of research and discovery instead of relying on mere repetition (p. 53)." In contrast, support for direct-instruction typically comes from information processing developmental theories that emphasize the gradual accumulation of knowledge. Studies by leading information-processing theorist Klahr and colleagues (2001, 2004) support direction instruction as the most efficient way to convey knowledge in a limited time frame.

Could the different values of education by Piagetian and Information Processing theories parallel different appreciation of conceptual understanding found in each developmental theory's operational definitions? Piagetian measurement of conceptual understanding relies upon novel tasks that 'lure' children without the concept to give a false response while only fully appreciating the concept allows for the true response. The three-mountains task involves the lure of your own perspective while answering for another. The lure of mass' seeming centrality to the sway of a pendulum lures children away from hypothetical-deductive reasoning in the pendulum task. When information processing theorists like Siegler and colleagues (1987) turn

Piagetian tasks into familiar component rules for children, Piagetian theorists like Liben (1987) suggest the tasks no longer measures deep conceptual development, but everyday learning. Information processing theorists also care about deeper conceptual understanding; deeper conceptual understand is recognized by transferring skills a greater “distance.” For example, the strongest evidence for direct instruction over inquiry-learning is better performance on near and far transfer tasks (e.g., Klahr & Li, 2005). I hypothesize direct instruction will outperform inquiry learning on tasks transferring knowledge across situation or procedure, but I predict the opposite for showing knowledge despite a conceptual lure.

Method

After one of four lessons about torque with the Piagetian balance beam task, 206 college students completed 24 test items examining four kinds of conceptual understanding. I designed the lessons to parallel 4 externally-valid learning situation analogs (Table 1): (1) *free-discovery* that was only provided with a goal but otherwise unstructured (like science museum exhibits), (2) *scaffolding* where the experimenter intervened in free-discovery at pre-established points to guide discovery toward key steps in understanding torque (like parent-child jig-saw puzzle completion) (e.g., McNaughton & Leyland, 1990) but with a more structured experimenter role for consistency across participants), (3) *inquiry* with scaffolding and additional summary statements like, “Now we see that …” by the experimenter to make students’ discoveries explicit (like typical inquiry learning classrooms as reported in ethnographic research (e.g., Roth, 1996)), and (4) *direct instruction* where the experimenter explained torque, used key vocabulary, and worked out several examples. In all 4 lessons students manipulated the same balance beam and the examples in direct instruction matched the scaffolds in the scaffolding and inquiry conditions.

Following instruction, students completed a test with 6 items of each of 4 kinds: base problems (i.e., like the balance beam), situation transfer (e.g., see-saw instead of balance beam), mathematical transfer (e.g., answer with weight on balance beam instead of predicting which side will drop), and conceptual lure (e.g., a tug-of-war where numbers were set up like torque problems but torque was irrelevant). Students participated either individually or in small groups of up to four.

Results

I conduct 4 (lesson) by 2 (group size) ANOVA to predict each of the four kinds of conceptual understanding test items (Figure 1). Significance of results was identical to ANOVA treating group size as a continuous covariate; since there were no main effects of or interactions with group size, no statistics are explicated. There was a significant main effect of lesson on base problems, $F(3,192)=35.621$, $p<.0005$. Post hoc tests using LSD suggest direct instruction outperformed free-discovery and scaffolding, but direct instruction and inquiry performed comparably. I chose LSD to maximize the chances of finding a significant difference if present; this maximized the chances of falsifying my conjecture that direct-instruction would not actually out-perform inquiry. There was a significant main effect of lesson on situation transfer problems, $F(3,192)=14.832$, $p<.0005$. Post hoc tests reveal direct instruction outperformed free-discovery and scaffolding, but direct instruction and inquiry performed comparably. There was a significant main effect of lesson on math transfer problems, $F(3,192)=22.332$, $p<.0005$. Post hoc tests reveal direct instruction outperformed free-discovery and scaffolding, but direct instruction and inquiry performed comparably. There was a significant main effect of lesson on conceptual lure problems, $F(3,192)=2.872$, $p=.038$. In stark contrast to the other three kinds of understanding, post hoc tests reveal inquiry and scaffolding performed comparably and they outperformed the comparably performing direct instruction and free-discovery.

Discussion

Consistent with information processing accounts, direct instruction outperformed free-discover and scaffolding on base problems, situation transfer and mathematic transfer. However, the lesson mimicking typical inquiry-learning classrooms performed the same as direct instruction. Consistent with Piagetian accounts, the inquiry-classroom and scaffolding conditions outperformed direct-instruction on conceptual-lures. Studies like this help us further theoretical debates within developmental psychology while providing practical solutions for education. While direct instruction is effective and time-efficient, the extra time and effort of inquiry learning is especially beneficial when educators aim for their students to acquire the deepest forms of conceptual understanding.

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Table 1. Instructional Conditions

Condition	Description	External-Valid Analog
Free-Discovery	only goal provided	science museum exhibits
Scaffolding	guidance w/ probes to aid discovery	parent-child informal learning like puzzle completion (e.g., McHaughton & Levian, 1990)
Discovery w/ Summation	scaffolding with short teacher statements clarifying general principle, “Now we know that …”	inquiry learning classes reported in ethnographic research (e.g., Roth, 1996)
Direct-Instruction	Teachers describes torque with key vocabulary and completes several examples	typical classroom

Figure 1. Participant Performance by Condition and Kind of Assessment Problem