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Yes, We're Giving You The Answers:

Why Step-by-Step Solutions are a Superior Instructional Model

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Overview:

Providing students fully explained solutions to their homework problems with the intention of improving the learning experience appears counterintuitive at first glance. If the mind learns from doing, from repetition, then how could such a philosophy benefit the learning process? In quantitative subjects like Physics, Algebra, Calculus and Chemistry, the pervading belief has long been to make students iron out the problems and concepts on their own – that sifting (and sometimes struggling) through the myriad equations, formulas and theories should, presumably, produce a stronger grasp of the material and a greater ability to retain critical knowledge. This class of thought, however, has run up against landmark studies conducted in the past two decades that go a long way toward challenging longstanding assumptions. (Jump to research)

A growing number of educational psychologists have argued that providing solutions to students accelerates and strengthens the learning process. In one such study, Tamara Gog, Fred Paas and Jeroen Merrienboer (2004) conclude that students need to be able to recognize similar features from the same type of problems in order to reach a solution, and that students spend too much time and cognitive capacity looking for irrelevant things rather than figuring out the schemata in solving the problem (84-85). Considering the well-documented struggles myriad students experience in math and science subjects, and nearly 20 years worth of data-driven momentum, step-by-step solutions (also known as worked examples) should be more frequently considered for inclusion into instructional models, or should at least enter the discussion. By further analyzing the work done by Gog, Paas, Merrienboer and several of their academic counterparts, educators and students alike stand to gain a more balanced view on the potential utility of providing step-by-step solutions.

Historical research and experiments:

The field of educational psychology has been recognized for more than 100 years, dating back to Thomas James' 1899 series of published lectures, Talks to Teachers on Psychology. The field gained momentum after Jean Piaget's theory of cognitive development altered the way educators conceived and constructed lesson plans. As the 21st century approached, educational studies increasingly focused on niche applications, from gender-specific learning styles to the utility of worked examples. Australian psychologist John Sweller is largely credited with pioneering the debate surrounding worked examples through his formulation of the "cognitive load" theory in the 1980s. Three of the most influential studies at the heart of the worked example debate are outlined below.

William M. Carroll:

The argument in favor of step-by-step solutions has most notably been trumpeted by William M. Carroll, whose 1994 article "Using Worked Examples as an Instructional Support in the Algebra Classroom," published in the Journal of Educational Psychology, proved students' superior performance when allowed to learn from step-by-step solutions relative to peers who were not provided solutions. Carroll conducted two experiments: The first involved high school students learning how to translate English expressions into algebraic equations, and the second focused on students in a remedial mathematics class receiving individual instruction. In both experiments, one group was provided step-by-step solutions as part of the "regular classroom instruction" and as "support for homework," while the control group was taught through more traditional, trial-and-error methods. Carroll tracked and evaluated all students' progress throughout the learning process and then, most tellingly, through tests at the end of the learning cycle.

The results Carroll reported showed that the students using step-by-step solutions as instructional support were at a significant advantage in both the time required to learn the material and their ability to retain material. Carroll (1994) writes: "Students using worked examples outperformed the control group on posttests after completing fewer practice problems; they also made fewer errors per problem and fewer types of errors during acquisition time, completed the work more rapidly, and required less assistance from the teacher," (360). The critical element of Carroll's analysis was that improvement was shown after the worked examples were taken away – not just on assignments and during conversation when the step-by-step support was still present. "This indicates that the worked example students were not just mindlessly copying the examples," Carroll writes. "Rather, they were forming schemata that linked English words to algebraic representations," (363).

John Sweller and Juhani Tuovinen:
Several of the academics writing on the subject of worked examples will use the term "schemata" in association with John Sweller, who was one of the first to research the topic and draw game-changing conclusions. Sweller conducted experiments involving the use of worked examples in teaching mathematics; the results he gathered compared almost identically to Carroll's experiments. One of Sweller's most important takeaways was that step-by-step solutions reduced mental effort or "cognitive load" by allowing students to locate and understand different schemata, which helps in solving problems with repetitive elements. According to Sweller (1999), natural cognitive load is necessary to carry out tasks, but there is "extraneous" cognitive load brought on by "the way the instructional material is taught," (335). Sweller goes on to state that one of the foremost advantages of worked examples is their ability to effectively reduce this extraneous cognitive load and "enhance learning," (335).
(…) This study fulfills this expectation," (131)

Sweller, Paas and Alexander Renkl:
Sweller, Carroll and several other colleagues have continued to research the effectiveness of step-by-step solutions, turning recently to more intense mathematical analysis of their findings, and have found no evidence that would refute their research conclusions. A 2003 edition of the Educational Psychologist published a follow-up report by Sweller, Paas and Alexander Renkl titled "Cognitive Load Theory and Instructional Design: Recent Developments" that quantified the "transfer performance" after learning from worked examples. They found that students in the test group needed 45 percent less time than the control group to solve conventional problems and study their solutions. The study emphatically concludes that, "In (quantitative) domains, problem solving requires a combination of rule-based and knowledge-based behavior, which implies a necessity to transfer acquired knowledge and skills. It is exactly these domains that are characterized by high processing load, in which the largest effects of worked examples could be expected (…) This study fulfills this expectation," (131).

Resistance:
The shortage of credible, researched alternative viewpoints is telling in the case of worked examples. The resistance that is widely met when suggesting the use of step-by-step solutions is fueled by little more than conventional thought and unchallenged fears of student misuse. That's not to say, however, that there hasn't been continuous and active discussion on the topic of cognitive load theory. Several studies conducted within the last 10 years argue that the existence of worked examples alone will not always augment learning – as with anything academic, there is a responsibility shared by both the learner and instructor. In her 2006

essay entitled "When worked examples don't work: Is cognitive load theory at an Impasse?" educational psychologist Roxana Moreno (2006) argues that the design of worked examples, the type of cognitive activity promoted by the worked examples, and individual differences are three major factors in the ultimate effectiveness of step-by-step solutions as an instructional model. Moreno never argues for the exclusion of worked examples, but rather for the improvement of the process by which step-by-step solutions are incorporated into the learning process. In her conclusion, Moreno states that "valid criticisms can be raised against any existing theory of cognition, and that such criticism is essential to progress," (178-179).

Although psychologists like Moreno have raised important questions that contribute to a larger effort to perfect the use of worked examples, there is an absence of viable counterarguments to the general theories proposed by Sweller, Carroll and other pioneers in their field. In Carroll's 1994 study, he provides a final example of three teachers who agreed to use a worked example format for three days in teaching addition and subtraction of polynomials. Those three days were enough to convert the teachers to Carroll's stance. "These teachers reported that students needed less initial teacher explanation and less teacher support during practice than usual in their classrooms," Carroll writes. "Furthermore, their students actively used the worked examples to self-correct mistakes and to monitor their understanding," (365). As Carroll's example demonstrates, the initial resistance hurdle is the hardest for step-by-step solutions to jump over; the problem lies not with the method itself, but with the all-too-common reliance on established norms.

How Cramster.com fits in:
For the millions of U.S. students who give up on math or science problems after long bouts of staring at an equation atop a blank sheet of paper, worked examples can provide a haven of understanding and confidence. At sites like Cramster.com, students enter not having to feel embarrassed about the level of help they require, and exit with the knowledge and learning capacity fostered through step-by-step solutions and the assistance of the Cramster community. Moreover, Cramster.com provides a proper context for the inclusion of worked examples, with the addition of a question-and-answer board, live chat, practice problems and subject-based resources so that students can solidify and apply the knowledge they have gained from seeing problems explained step by step. No doubt, the work of Carroll and others is confirmed when 90 percent of Cramster members report that they were able to achieve or raise the grade they desired because of the help they received on the site.

Call to action:
The primary mission of Cramster.com, just as it is for thousands of educators around the world, is to further student understanding of challenging subjects. At first glance, the methods employed on the site might run contrary to traditional practice, but in the end, the educational benefit speaks for itself. Step-by-step solutions are by no means a panacea, but by all means, they are a deserving candidate for inclusion into classrooms and homes everywhere.

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