

## The Mathematical World > Reasoning

### Research on Student Learning

Students of all ages show a tendency to uncritically infer cause from correlation. <sup>[1]</sup> Some students think even a single co-occurrence of antecedent and outcome is always sufficient to infer causality. Rarely do middle-school students realize the indeterminacy of single instances, although high-school students may readily realize it. Despite that, as covariant data accumulate, even high-school students will infer a causal relation based on correlations. <sup>[2]</sup> Further, students of all ages will make a causal inference even when no variation occurs in one of the variables. <sup>[3]</sup>

Students seem to make valid judgements about situations in which variables have an effect on the outcome earlier than in situations in which variables have no effect on the outcome, or in situations in which, given the current evidence, it is not possible to decide about a variable's role. <sup>[4]</sup> Faced with inconclusive data, students may draw conclusions in line with their predictions. <sup>[5]</sup> Faced with no correlation of antecedent and outcome, 6th-graders only rarely conclude that the variable has no effect on the outcome. <sup>[6]</sup> Ninth-graders draw such conclusions more often. A basic problem appears to be understanding the distinction between a variable making no difference and a variable that is correlated with the outcome in the opposite way than the students initially conceived. <sup>[7]</sup> Another issue is that students are often not aware that all measurements are inevitably subject to uncertainty (or error) and that two measurements of a quantity that has not actually altered are therefore likely to differ. <sup>[8]</sup>

A challenge for students of all ages is to generate and interpret evidence that is inconsistent with their prior beliefs. <sup>[9]</sup> When data are at odds with students' prior beliefs, experiences, or predictions, students may draw conclusions in line with their prior beliefs or predictions (if their prediction is based on some underlying model of the phenomenon involved). <sup>[10]</sup> Changing beliefs in response to anomalous data may be impeded primarily because students do not make the correct observations (because of their prior belief) rather than because students ignore, distort, discount the observations, or claim that the observations do not hold in other cases. <sup>[11]</sup>

Students of all ages tend to consider the effect of only a single quantity on another single quantity. <sup>[12]</sup> Even in multivariable situations, students tend to consider only one factor as possibly influencing the situation, and as a consequence, may overlook other possible influential factors. <sup>[13]</sup> Similarly, students have trouble explaining outcomes that are the additive product of two individual variables and may fluctuate from one variable to another trying to explain which single variable produced the outcome. <sup>[14]</sup>

Most high-school students will accept arguments based on inadequate sample size, accept causality from contiguous events, and accept conclusions based on statistically insignificant differences. <sup>[15]</sup> More students can recognize these inadequacies in arguments after prompting (for example, after being told that the conclusions drawn from the data were invalid and asked to state why). <sup>[16]</sup>

When constructing or evaluating arguments, the following problems appear in student reasoning: problems with validity of arguments, a naive conception of argument structure, inappropriate effects of core beliefs on argumentation, inadequate sampling of evidence, and altering the representation of argument and evidence. <sup>[17]</sup>

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