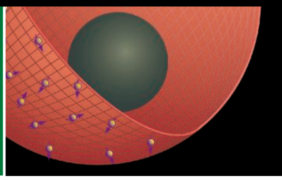

LETTERS

edited by Jennifer Sills

Testing the Limits of "Concrete" and "Generic"

HERE ARE TWO WAYS TO INTRODUCE THE MATHEMATICAL GROUP OF ORDER THREE: (I) SAY that it is the set of 0, 1, and 2, together with the operation of "addition modulo 3." (ii) Say that it is made of three elements a, b, and c, together with an explicitly defined operation.

J. A. Kaminski *et al*. ("The advantage of abstract examples in learning math," Education Forum, 25 April, p. 454) labeled as "concrete" the examples based on the first definition and labeled as "generic" the ones based on the second.

In Kaminski *et al*.'s study, students' transfer of knowledge was tested by an assessment that followed the second, "generic" definition, regardless of the definition the students were introduced to during their training. It is thus not surprising that students performed better if they first practiced using the "generic" examples than they did if they trained on the "concrete" ones. Because the transfer test was more similar to one training condition, it would be unwise to generalize the results to the advantages of abstract examples in other situations, as suggested by the Education Forum's title.

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"Concrete" Examples a Fraction Too Abstract

AFTER EXAMINING THE SUPPORTING ONLINE Material for the Education Forum by J. A. Kaminski *et al*., "The advantage of abstract examples in learning math" (25 April, p. 454), I doubt that abstract examples are better. Rather, the study shows that the effectiveness of teaching examples depends less on whether they are "generic" or "concrete" (a somewhat confused distinction) and more on the examples' affordances that lead students to (or distract from) the learning goal.

In the study, students must learn the abstract mathematical concept of mod 3. Teaching such a concept requires appropriate modeling. The study's "generic" examples (circles, diamonds, and flag shapes) and the assessment examples both serve this purpose well. Each set of examples uses three distinct symbols, which help students master the specific, limited concept. A set of shapes does not lead to confusion because it does not introduce numerosity, which is irrelevant to mod 3. By contrast, the three "concrete" examples seem geared to teaching the broader, generalized concept that includes mod 4, mod 5, and so on. These examples (such as measuring cups 1/3, 2/3, or 3/3 full) easily generalize to higher integer orders by increasing the number of symbol states (e.g., by dividing the cups into fourths, fifths, and so on, instead of thirds), but invite confusion when introducing the study's limited concept. This interferes with the lesson. Arguably, the intuitive appeal to numerosity in these "concrete" examples (invoking specific fractions) makes them more, rather than less, abstract than the "generic" example (using only shapes and no numbers).

The symbols used in the assessment, although showing hints of numerical associations, do not obviously invoke numerosity. Moreover, the assessment is almost identical to the "generic" example. It is no wonder that students who learned using the "generic" example performed better on the assessment than those who learned using the "concrete" example(s). The numerical—even abstract—nature of the "concrete" examples distracted students instead of helping them.

The study clearly demonstrates the possibility of constructing confusing "concrete" examples of a particular concept, but we cannot infer that "generic" examples are always superior to "concrete" examples. Whether a confusing example is "concrete" or "generic" is beside the point.

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Concrete Examples Must Jibe with Experience

IN THEIR EDUCATION FORUM "THE ADVANTAGE of abstract examples in learning math" (25 April, p. 454), J. A. Kaminski *et al*. investigated several ways to teach the mathematical concept of mod 3, in which all numbers are simplified to their remainder when divided by 3. (For example, 3 divided by 3 has a remainder of 0, 4 divided by 3 has a remainder of 1, and 5 divided by 3 has a remainder of 2. In mod 3, the numbers 3, 4, and 5 are equal to their remainders: 0, 1, and 2, respectively.) To teach this concept to students, Kaminski *et al.* represented the three possible mod 3 values with abstract examples (such as a circle, diamond, and flag shape) and with concrete examples (such as three cups of water in a measuring cup). On the basis of student performance on post-tests, Kaminski *et al*. concluded that using abstract examples was the more effective teaching strategy. I disagree. I believe that the vocabulary and examples

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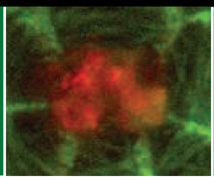

Force and form

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used in the experiment conflicted with students' prior knowledge, and it was this confusion and not the concrete example strategy that led to the reported results.

In theory, concrete examples (such as measuring cups of water) activate knowledge stored in memory (such as baking a cake), and this connection facilitates learning and problem solving (*1*). However, concrete examples are counterproductive if they are inconsistent with prior knowledge. This is the case for the measuring cup example in Kaminski *et al*.'s experiment. For example, Rule 2 states that combining 1/3 cups with 2/3 cups produces a filled cup and refers to the filled cup as the "left over." This use of the phrase "left over" is inconsistent with its use in everyday language. Whereas the concrete strategy had the potential to help the students understand the new concept, these misleading labels most likely led to confusion instead.

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Response

MOURRAT RAISED THE POSSIBILITY THAT THE examples used in our Education Forum are mathematically different across conditions and that these differences led to differences in performance on the assessment (transfer task). We argue that the mathematics underlying the generic and concrete examples was identical and that both sets of examples met the definition of a commutative group of order three (*1*). This concept can be accurately instantiated through numbers, shapes, or scenarios such as filling measuring cups or the children's game. Therefore, there is every reason to believe that the differences between the examples we used are not mathematical, but cognitive.

Cutrona and Mourrat further suggest that the difficulty transferring knowledge from the concrete examples stems from possible numerical aspects of the concrete examples that were absent from the transfer task. Because the concept of a mathematical group can be instantiated in an unlimited number of ways, only a subset of which involve numbers (as modular arithmetic), we argue that numerical characteristics are extraneous and as such are part of concreteness. Therefore, it is possible this numerical information could hinder transfer to non-numerical domains. We have foreseen this possibility and have already conducted research to investigate transfer from a numerical domain. Our (unpublished) results do not contradict our findings reported in the Education Forum.

Reed proposes that participants failed to transfer from the concrete examples because these examples are inconsistent with prior knowledge. We disagree and believe that the rules and the storyline of the concrete examples are consistent with prior knowledge (see Supporting Online Material for the Education Forum). More important, if the concrete examples were inconsistent with prior knowledge, then why did they result in fast and efficient initial learning (*2*)?

We do not deny that transfer can occur when students learn using concrete examples. Rather, we have asked whether learning multiple concrete examples is the most efficient route to promoting transfer. Our data clearly suggest that it is not. Generic examples that are neither realistic nor grounded in prior knowledge resulted in significant transfer, while concrete examples did not.

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Letters to the Editor

Letters (~300 words) discuss material published in *Science* in the previous 3 months or issues of general interest. They can be submitted through the Web (www.submit2science.org) or by regular mail (1200 New York Ave., NW, Washington, DC 20005, USA). Letters are not acknowledged upon receipt, nor are authors generally consulted before publication. Whether published in full or in part, letters are subject to editing for clarity and space.

Gene Regulation in Evolution: A History

AN OTHERWISE INTERESTING AND INFORmative News Focus story by E. Pennisi, "Deciphering the genetics of evolution" (8 August, p. 760), was marred by a flawed recounting of the key scientists responsible for advancing the importance of gene regulation in evolutionary change. In particular, the statement "Early suggestions that gene regulation could be important to evolution came in the 1970s. …" is incorrect.

As early as the 1940s, developmental geneticists such as C. H. Waddington and Richard Goldschmidt began to explore the possible involvement of gene regulation in evolution (*1*). Then, in 1969, Roy J. Britten and Eric H. Davidson published a detailed and highly influential paper in *Science* (*2*), "Gene regulation for higher cells: A theory," which clearly and explicitly argued for the importance of gene regulation in evolution. For example, on p. 356 of this paper, Britten and Davidson concluded, "At higher grades of organization, evolution might indeed be considered principally in terms of changes in the [gene] regulatory systems."

Britten and Davidson's theory of gene regulation was inspired in large part by Britten's groundbreaking work in the 1960s on DNA reassociation kinetics, which led him to discover that repetitive sequences are ubiquitous in eukaryotic genomes. Some of these repetitive sequences were later shown to influence gene regulation, and they often consist of transposons and transposon remnants that are able to cause changes in gene regulation. Because of these developments, some feel that Britten should have shared the 1983 Nobel Prize in Physiology or Medicine with Barbara McClintock for the discovery of mobile genetic elements.

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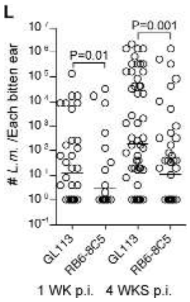
CORRECTIONS AND CLARIFICATIONS



Reports: "In vivo imaging reveals an essential role for neutrophils in leishmaniasis transmitted by sand flies" by N. C. Peters *et al*. (15 August, p. 970). In Fig. 4L, some data points were inadvertently omitted during production. The corrected panel is shown here (left). The interpretation of the data is unchanged.

Reports: "Hidden neotropical diversity: Greater than the sum of its parts" by M. A. Condon *et al*. (16 May, p. 928). The first sentence of the main text was erroneous and should be replaced with the following two sentences: "Insects are extraordinarily diverse, with estimates ranging in number from 3 million to 30 million species (*1*). Recent studies focus specifically on the diversity of tropical herbivorous insects (*2*, *3*) and suggest that the diversity of herbivorous insects is a function of plant diversity (*2*), but the degree to which specialization shapes that function is contentious (*3*)." This correction supersedes the correction published in the 5 September issue.

Reports: "Pairing without superfluidity: The ground state of an imbalanced Fermi mixture" by C. H. Schunck *et al*. (11 May 2007, p. 867). Following previous work, we interpreted a spectral gap observed in the radio-frequency (rf) spectrum of a strongly imbalanced Fermi mixture as evidence for fermion pairs that do not form a condensate even at very low temperature. This conclusion was based on the assumption that unitarity-limited interactions in both initial and final states cancel out. However, recent experiments by the same group [*Phys. Rev. Lett*. **101**, 140403 (2008); *Nature* **454**, 739 (2008)] have shown that the observed spectra were strongly affected by final-state interactions. Using a new superfluid system where these interactions were weak and rf tomography to obtain local spectra without inhomogeneous broadening, the following conclusions were reached: (i) Similar to previous observations with strong final-state interactions, the minority spectrum does not show any signature of the superfluid phase transition and features similar interaction shifts in the superfluid and normal phases. (ii) In contrast, a comparison with the majority spectrum reveals that identical pairing peaks are present in both spectra only in the superfluid phase, and that the two peaks lose overlap in the normal region. (iii) This suggests that the spectral gap in the minority spectrum of the highly imbalanced normal phase should be interpreted as a signature of polaronic binding instead of evidence for pairs. (iv) The previous identification of the spectral gap with a pairing gap or a superfluid gap is incorrect. However, we have now observed locally the presence of both a pairing peak and a quasiparticle peak in the majority spectrum. The splitting between these peaks is directly related to the superfluid pairing gap.

TECHNICAL COMMENT ABSTRACTS

Comment on "An Association Between the Kinship and Fertility of Human Couples"

Rodrigo Labouriau and António Amorim

Helgason *et al*. (Reports, 8 February 2008, p. 813) reported a positive association between kinship and fertility in the Icelandic population. We point out that the data further suggest that fertility initially increases with kinship and then decays. This is supported by another large study on the Danish population suggesting a superposition of effects of inbreeding and outbreeding depression on human fertility.

Full text at www.sciencemag.org/cgi/content/full/322/5908/1634b

Response to Comment on "An Association Between the Kinship and Fertility of Human Couples"

Agnar Helgason, Snæbjörn Pálsson, Daníel F. Guðbjartsson, Þórður Kristjánsson, Kári Stefánsson

Analyses of 137,844 Icelandic couples born between 1800 and 1965 reveals a monotonic drop in fertility with increasing marital radius (distance between the birthplaces of spouses). Marital radius was moderately correlated with kinship between spouses. This correlation was strongest during the peak of urbanization (1875 to 1925) but very weak after 1950. These results raise doubts about the use of marital radius as a proxy for kinship in contemporary human populations.

Full text at www.sciencemag.org/cgi/content/full/322/5908/1634c