Counterexample and review worksheet

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In a high school Geometry course, we teach examples and counterexamples along with conditional statements and logical reasoning. But this piece is a missing key before kids get to that stage. It's not really an automatic part of Pre-Algebra or Algebra 1. After noticing kids with a lot of trouble thinking critically to determine whether statements are true or false, I've realized that we need to expand the explicit teaching of examples and counterexamples beyond Geometry class. In almost every topic of study throughout their math courses, kids can benefit from practice and instruction on this skill. They need to be learning how to test different cases, organize information, and draw conclusions about the math properties that are at play. The easiest and most concrete way I've found to do this is through "always, sometimes, never" questioning. Kids cannot think through these types of questions without mentally testing cases. And if you go a step beyond to have them support their answers, they will be forced to justify by using both examples and counterexamples. BONUS: This type of question almost ALWAYS inspires some solid "math talk," so make sure to let your classes work in pairs or showcase their reasoning at the board to get that conversation going. Here are some examples to try to incorporate: Often, students may think they know the answer and then in testing, they'll come across a different situation that violates the "rules" they were imagining originally. Make sure to have them try every case they can think of that fits the "premise" criteria and then see if they can reach a conclusion about whether each statement is always true, sometimes true, or never true. Samples with Quadratics: Always true, sometimes true, or never true?? The graph of a quadratic function with a positive linear term crosses the x-axis. A quadratic equation contains no negative terms and has two real solutions. A quadratic equation with a negative leading coefficient is represented by a parabola opening upward. (more quadratics questions) Have kids try these samples, and be sure that they support their claims by providing both examples and counterexamples. See if they can develop some systems to organize their work and be sure that they have tested every possible case. Samples with Integers: Always, sometimes, or never true?? The quotient of two nonzero integers is negative. The sum of three negative integers is negative. The difference between a positive and a negative number is positive. Students will need to test in different orders and justify their answers by showing each case and whether it turned out to be a true or false statement. These ones work well at the board, because students can watch one another draw the figures and see which cases work out. If you have access to geometry software like GeoGebra, you can use that as well. Have students draw each triangle and see if they can drag a vertex to meet the criteria. Samples with Triangles: Always, sometimes, or never true?? A triangle has two right angles. A right triangle is not scalene. A scalene triangle has two acute angles. (more triangle questions) All the sets I develop with this type of questioning include 36 statements to classify. My favorite 2 ways for students to work through these types of questions are in partners in a worksheet, or as teams with a sorting activity with a notebook on the side. PARTNER WORKSHEET: I lay the statements out in a grid so that when they color each statement that is NEVER true RED, each statement that is ALWAYS true BLUE, and each statement that is SOMETIMES true PURPLE, it creates a pattern that I can check really easily in just 2 seconds. This makes it really easy to check it over as I walk around and just point to ones that I can see are incorrect. They go back to the drawing board on those statements and continue their (sometimes heated) discussions! (Fractions, Decimals, Percents version) SORTING ACTIVITY:I cut the statements (larger print version) into cards and have small teams or pairs of students sort them into categories based on whether they are always, sometimes, or never true. Be sure that they have notebooks available, because at any moment they may be required to provide examples to support their answers. You can also hand out the cards and have students come up to the front in a whole-class setting to tackle challenging ones. These are pretty versatile. It's nice to hear a student model an explanation and show the class how they tested different cases to reach a conclusion. Thank you for your participation! Logic Worksheet (This logic worksheet was prepared by one of the course TAs, Michael Rubin, to help students learn the notion of logical validity. This worksheet may help prepare you for any upcoming quizzes on logic in your discussion section.) INTRODUCTION Validity: A deductive argument is valid if it has a form that would make it impossible for the premises to be true and the conclusion false. If a deductive argument is valid, then its premises' being true would guarantee that its conclusion is true. To test whether or not an argument is valid, you should first imagine that the premises are true—whether or not they actually are—and then ask yourself, without appealing to any other knowledge you have, could you still imagine the conclusion being false? If you can, the argument is invalid. If you can't, then the argument is valid. Note that validity is a matter of the form or structure of an argument, as opposed to the content. If an argument is valid, then any other argument with the same logical structure will also be valid, regardless of its content. Also, keep in mind that an argument can be valid even if its premises are not actually true. An argument that has true premises (regardless of whether it is valid or invalid) is said to be factually correct. An argument that is both valid and factually correct is sound . Some hints on determining validity: When you are checking the validity of an argument, you may need to visualize what the world would have to be like if its premises were true. Sometimes Venn diagrams can prove helpful. Consider this argument, for instance: 1. All dogs are cats 2. All cats are lizards 3. Therefore, all dogs are lizards Clearly, this argument is not factually correct, for the premises are false. But it may be of a valid argument form. To check this, we must imagine a possible world in which all the premises are true. So consider premise 1. We can represent what it is saying by drawing two circles. One circle represents a collection of all the dogs in the possible world, and the other circle represents all the cats. Since the premise says that ALL dogs are cats, we know that every member in the circle of cats must also be a member in the circle of dogs. So we must put the dog circle INSIDE the cat circle. Keep in mind that there are no premises telling you that all CATS are DOGS. Thus, there should be some leftover area of the cat circle that falls outside of the dog circle, to show that there may be some cats that are not dogs. Now, look at the second premise. If all cats are lizards, then the whole CAT circle (with the DOG circle still inside it) must be placed within the circle of all the lizards in the world. At this point, we should have an accurate representation of the premises. Do they guarantee the conclusion? That is to ask: is it possible in that world for the conclusion to be false? Since you will notice that there is no area of the dog circle outside the lizard circle, you should see that if these premises were true, the conclusion must also be true. The argument is therefore valid. "if...then" premises: It may be possible to use Venn diagrams to help clarify "if...then" premises. Suppose we have a premise that says "if P then Q". We can think of this as stating that whenever P is true, then Q must also be true. Another way of putting it is by saying: All cases of P are also cases of Q. If you find the Venn diagrams helpful, you could represent this by drawing a large Q-circle with a smaller P-circle inside of it. Notice that this leaves with some area of the Q-circle that is not also in the P-area. That is because "if P then Q" does not mean that there cannot be instances where Q is true, but P is false. An important thing to notice, however, is that if you say that Q is false, then you must also say that P is false. Perhaps you could represent a statement (such as 'P' or 'Q') as being false by crossing out the area of its circle. So, for example, if another premise says that Q is false (or simply not-Q) then you could draw an X through the whole Q circle. Of course, this means also drawing an X through the P circle as well, so P must be false too. Below are some arguments. For each argument try to determine whether or not it is valid (you may want to take note of whether or not you think the argument is sound as well). It is worth taking the time to symbolize each argument (for instance, using 'P's and 'Q's to stand for statements. Pay attention to which symbolized arguments are valid and which are invalid. Doing so will help you recognize valid and invalid arguments with greater ease. I have included answers with some comments following the exercises. EXERCISES: A. 1. If Jane has a cat, then Jane has a pet 2. Jane has a cat 3. Therefore, Jane has a pet B. 1. If Jane has a cat, then Jane has a pet 2. Jane has a pet 3. Therefore, Jane has a cat C. 1. If Jane has a cat, then Jane has a pet 2. It is not the case that Jane has a pet 3. Therefore, it is not the case that Jane has a cat D. 1. If Jane has a cat, then Jane has a pet 2. It is not the case that Jane has a cat 3. Therefore, it is not the case that Jane has a pet E. 1. If pigs fly, then hell has frozen over 2. Pigs fly 3. Therefore, hell has frozen over F. 1. If Bush is president, then a Republican is president 2. A Republican is president 3. Therefore, Bush is president G. 1. If E.T. phones home, then blue is Joe's favorite color 2. It is not the case that blue is Joe's favorite color 3. Therefore, it is not the case that E.T phones home H. 1. It is not the case that Yoda is green 2. If Darth Vader is Luke's Dad, then Yoda is green 3. Therefore, it is not the case that Darth Vader is Luke's dad I. 1. Dan plays the cello 2. If Mary plays the harp, then Owen plays the clarinet 3. Therefore, it is not the case that Mary plays the harp J. 1. All smurfs are snorks 2. All ewoks are snorks 3. Therefore, All smurfs are ewoks K. 1. Kate is a lawyer 2. Therefore, Kate is a lawyer L. 1. If it is morally permissible to kill an 8-month old fetus, then it is morally permissible to kill a newborn infant 2. It is not the case that it is morally permissible to kill a newborn infant 3. Therefore, it is not the case that it is morally permissible to kill an 8-month old fetus M. 1. If Rufus is a human being, then Rufus has a right to life 2. It is not the case that Rufus is a human being 3. Therefore, it is not the case that Rufus has a right to life N. 1. All anarchists are socialists 2. All socialists are totalitarians 3. Therefore, all anarchists are totalitarians O. 1. No cat is a biped 2. All kangaroos are bipeds 3. Therefore, No cat is a kangaroo P. 1. If there is order in the universe, then God exists 2. There is order in the universe 3. Therefore, God exists Q. 1. Amy joins the Army, or Mary joins the Marines 2. It is not the case that Mary joins the Marines 3. Therefore, Amy joins the Army (Note: the word 'OR' is a logical term much like 'if...then', 'therefore' and 'it is not the case that...' Like these other terms, 'OR' is part of the structure or form of the argument, rather than the content.) R. 1. Ariel joins the Air Force or Nancy joins the Navy 2. Nancy joins the Navy 3. Therefore, Ariel joins the Air Force ANSWERS: A. 1. If P then Q 2. P 3. Therefore, Q Valid (Modus Ponens) B. 1. If P then Q 2. Q 3. Therefore, P Invalid This argument form is commonly mistaken as being valid. Notice that even if the premises are true, the conclusion could still be false: Jane could have a dog. C. 1. If P then Q 2. Not: Q 3. Therefore, Not: P Valid (Modus Tollens) D. 1. If P then Q 2. Not: P 3. Therefore, Not: Q Invalid This is another argument form that is commonly mistaken as being valid. Again, Jane could still have a pet even if she does not have a cat, maybe she has a bird. Her owning a bird is not ruled out by the premises. E. 1. If P then Q 2. P 3. Therefore, Q Valid (Modus Ponens) Notice that this argument is still valid even though (as far as we know) all the premises (and the conclusion) are, in fact, false. F. 1. If P then Q 2. Q 3. Therefore, P Invalid This is the same invalid form as argument B. Notice that all the premises and the conclusion are in fact true. Still, the argument is invalid: it is possible for all the premises to be true and the conclusion still be false. You can imagine a world in which the two premises are true, and yet George Bush is not president. Some other Republican could be president. G. 1. If P then Q 2. Not: Q 3. Therefore, Not: P Valid (Modus Tollens) This is the same argument form as argument C. This seem trickier than argument C since premise (1) in argument G asserts an unlikely relationship between what Joe's favorite color is and whether or not E.T. phones home. What could those two things have to do with one another? They probably have nothing to do with one another. Therefore, premise (1) is probably false. But to check the argument for validity we need to imagine that it is true. So we need to imagine that somehow, for some reason unbeknownst to us, if it is true that E.T. phones home, then it also will be true that Joe's favorite color is blue. H. 1. Not: P 2. If Q then P 3. Therefore, Not: Q Valid (Modus Tollens) This is the same argument form as argument C and G. The only difference is that the if-then statement is the second premise rather than the first. That's okay, the order of the premises is unimportant for determining validity. Also, don't be fooled by the actual falsity of the premises: IF they were true, the conclusion would have to be true as well. I. 1. P 2. If Q then R 3. Therefore, Not: Q Invalid J. 1. All x are y 2. All z are y 3. Therefore, x are z Invalid. You can see this by considering an argument of the same logical form that has premises that are easier to imagine being true (because they are true): 1. All humans are primates. 2. All gorillas are primates. 3. Therefore, all humans are gorillas. K. 1. P 2. Therefore, P Valid Obviously, if "Kate is a lawyer" is true, then it would be impossible for "Kate is a lawyer" to also not be true. But is this because of the logical form of the argument? Well, try uniformly substituting different sentences for 'P' and see what happens. (Remember, whatever you substitute for 'P' must go everywhere there is a 'P'.) However, this argument does beg the question, but that's a different question from the question of validity and invalidity. L. 1. If P then Q 2. Not: Q 3. Therefore, Not: P Valid (Modus Tollens) Same argument form as C, G, and H. M. 1. If P then Q 2. Not: P 3. Therefore, Not: Q Invalid Same invalid argument form as in argument D. Even if the premises are true, it is still possible that other life-forms besides human beings have a right to life. It is quite plausible to suppose at the very least that chimpanzees have a right to life. N. 1. All x are y 2. All y are z 3. Therefore all x are z Valid O. 1. No x is y 2. All z are y 3. Therefore, no x is z Valid. If it is hard to see why, try drawing a Venn diagram. P. 1. If P then Q 2. P 3. Therefore, Q Valid (Modus Ponens) Q. 1. P or Q 2. Not: Q 3. Therefore, P Valid. R. 1. P or Q 2. Q 3. Therefore, P Invalid. The premises don't guarantee that Ariel joined the Air force (though he might have.) Note: In logic, the word 'or' is usually understood in its INCLUSIVE sense. You should understand the first premise as saying something to the effect of: "either Ariel joins the air force or Nancy joins the Navy or both".Return to course homepage.

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