Teaching Common Errors in Applying a Procedure

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This study investigated whether or not the teaching of matched examples and nonexamples in the form of common errors would improve student performance in applying a procedure to previously unencountered instances, and whether the common errors would be most beneficial in generality form, in example form, or in both forms. Participants were 141 first-year music students, who were randomly assigned to four groups and given the task to learn a procedure that was presented in a self-contained booklet. A pretest-posttest experimental design was used, with a prerequisite test given as a screening device. The two independent variables were the absence and presence of the common errors in the generality form and in the example form (2 × 2 factorial design). Results indicated that the teaching of common errors in the generality form significantly improved learning a procedure at the application level of behavior.

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The use of nonexamples matched with examples has been found to be an effective strategy in improving concept attainment. Merrill and Tennyson (1977) define nonexamples as negative instances paired with positive instances with minimum within-pair variation of irrelevant attributes. Their use in concept instruction has been found to reduce common errors of overgeneralization, undergeneralization, and misconception (Tennyson, Woolley, & Merrill, 1972). Also, the use of matched nonexamples in concept instruction has been found superior to the inclusion of only positive examples (Markle & Tiemann, 1969; Williams & Carnine, 1981). This leads one to speculate as to whether or not a similar set of prescriptions would benefit the teaching of other types of content at a use-a-generality (or intellectual skill) level.

Merrill (1983) distinguishes between remember-level outcomes and use-level outcomes, which correspond to Gagne's verbal information and intellectual skills, respectively. He further distinguishes among three types of content that can be learned at the use level: concepts, principles, and procedures. The latter two are forms of rule using in Gagne's (1985) taxonomy. Principles are cause-effect relationships or natural processes, both of which are discovered, whereas procedures are sequential steps invented and performed to achieve a goal. A variety of procedures can usually be invented to achieve any given goal (Merrill, 1983).

Although the list of experimental studies and theoretical work concerning the use of nonexamples in concept attainment is quite lengthy (see Clark, 1971; Tennyson & Park, 1980; and Jassal & Tennyson, 1981), their use has been largely overlooked in the teaching of other content types, such as procedures and principles. Ali (1981) looked at the use of positive and negative examples for teaching all content types, and noted that little has been done with their use in procedure learning. In addition, his lengthy literature review concerning sequencing, quality, and quantity of examples and nonexamples in concept learning, in comparison with the lack of such research cited for other types of content, exemplifies the lack of attention to the use of matched nonexamples to teach procedures.

Overall, the strategy components recommended for teaching a procedure at the use-a-generality level of performance are similar to those recommended for teaching a concept: a generality, some divergent examples, and some previously unencountered practice with feedback (Merrill, 1983). Therefore, it is surprising that only recently have some instructional theorists begun to suggest the use of nonexamples in teaching a procedure (Ali, 1981; Merrill, 1983; and Gropper, 1983). A matched nonexample for a concept is the side-by-side presentation of an example of the concept with a nonexample that is as similar to it as possible (hence commonly classified incorrectly as an example by novices). It helps the learner by pointing out a common error that novices make, so that they can avoid that error in the future. Following the same rationale, a matched nonexample for a procedure is the demonstration of a common error in a performance of the procedure, along with a demonstration of the corresponding correct performance.

A literature search has not revealed any experimental studies of the effectiveness of this strategy. However, three unpublished experimental studies recently have been completed. They each addressed the presentation of common errors matched with the correct performance in teaching a procedure at the use-a-generality level. All of the studies used college students and the pretest-posttest design (Campbell & Stanley, 1963). Two of the three studies (Tinklepaugh & Reigeluth, 1984; and Garduno, Marcone, & Reigeluth, 1984) did not find any significant differences, although the means were in the predicted direction. Both studies were in booklet form, and the amount of student effort spent learning the procedure was not controlled.

The third study did find a significant difference (Bentti, Golden, & Reigeluth, 1983). In an audiovisual presentation, use-a-generality level learning was facilitated by the presentation of common errors matched with correct performance. The difference appears to have been made detectable (significant) by the use of a paced audiovisual presentation that controlled, to some degree, the amount of student effort.

This study proposes to answer the following questions:

1. In teaching a procedure, does the presentation of common errors matched with the correct performance affect mastery of the performance of the procedure?
2. Are common errors more beneficial when presented in the form of a generality or in the form of examples?

The independent variables in this study are common errors in generality form (absence and presence) and common errors in example form (absence and presence). To be matched nonexamples, common errors in example form are always matched with examples of the correct performance of the procedure. Similarly, common errors in generality form are presented simultaneously with a generality of the corresponding correct performance. The dependent variable is the correct performance of the procedure at the use-a-generality level of behavior.

It was hypothesized that: (1) students receiving the presentation of the common errors in the generality form would perform the procedure significantly better than students who did not; and (2) students receiving the presentation of the common errors in the example form would perform the procedure significantly better than students who did not.

METHOD

Students

One desired outcome c generalize the results tc the population attendi fore, one section (41 stu music theory at Syracu sections (46 students) o William Paterson Con New Jersey, and thre dents) of music theory munity College were s in the study. All of th domly assigned to fou the authors nor the pr which students were i

Design

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Task and Materials

The task entailed b musical interval with tave up from a given unencountered exar The instruction book pose of the instructi dure for building a m any given note." T sented the steps con of the procedure, medium difficulty w neously with the ger steps (see Figure 1). ceived the Common ure 2), which listed t for each interval. Th were subsequently was provided.

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METHOD

Students

One desired outcome of this study was to generalize the results to a wide segment of the population attending college. Therefore, one section (41 students) of freshman music theory at Syracuse University, three sections (46 students) of music theory at The William Paterson Community College of New Jersey, and three sections (54 students) of music theory at Onondaga Community College were selected to participate in the study. All of the students were randomly assigned to four groups, and neither the authors nor the proctors were aware of which students were in each group.

Design

The pretest-posttest control group design (Campbell & Stanley, 1963) was chosen as the experimental design. The control group received all the instruction except for the experimental variables (the common errors).

The statistical design was a 2 × 2 ANCOVA (Darlington, 1975). It was chosen because there were two independent variables in the study with two levels each, constituting the four cells, and because pretest scores between groups were unequal (requiring the use of pretest scores as a covariate).

Task and Materials

The task entailed building an ascending musical interval within the range of an octave up from a given note with previously unencountered examples (see Figure 1). The instruction booklet identified the purpose of the instruction: "to teach a procedure for building a musical interval up from any given note." The booklet then presented the steps constituting the generality of the procedure, and one example of medium difficulty was presented simultaneously with the generality to illustrate the steps (see Figure 1). All of the students received the Common Interval Chart (see Figure 2), which listed the number of half steps for each interval. Three divergent examples were subsequently given, but no practice was provided.

The procedure used in this study was one of several that could be used for the task. It was chosen by a content expert, who is a professor of music theory at Syracuse University.

A pilot study revealed that some students thought they were supposed to practice the procedure in the examples. Hence, the directions were rewritten in the conditional perspective (see Figure 1) and directly told the students that it was not necessary to perform the procedure in the examples because they would have an opportunity to practice the procedure later (in the form of the posttest).

Results of the pilot test also determined the amount of time students would be permitted to spend on each page in the main study. The time spent on each page was recorded for every student that completed the pilot test ($N = 7$), rounded off to the next 30-second interval. This was intended to ensure that sufficient time, but not too much time, was given. It was hoped that controlling the pacing of the instruction would help control student effort.

Treatments

The instruction was identical for all groups, with the exception of the following two variables: the common errors in generality form and the common errors in example form. The resulting four treatment groups are shown in Figure 3.

In both steps of the generality, the Control group and the Examp group received only the correct procedure. The Gen and Gen-Examp groups received the correct procedure and the reminder "*Be Careful,*" plus the statement of the common error for the step, followed by "THIS IS THE MOST OFTEN MADE MISTAKE" (see Figure 1).

In the example presented simultaneously with the generality, the Control group and Gen group received only an example of the correct procedure. The Examp and Gen-Examp groups received the example of the correct procedure matched with the most often made mistakes on that example. In the three examples that followed the generality, the two groups that received examples of the most often made mistakes were asked to circle the mistake before proceeding. Although this was an overt response, it was

PROCEDURE FOR BUILDING A MUSICAL INTERVAL UP FROM THE GIVEN NOTE

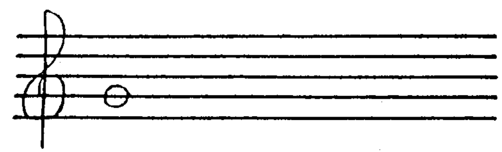
STEP 1A: You would begin on the given note, and *COUNT UP* the lines and spaces to the interval *NUMBER* requested.

STEP 1B: You would write in the note.

BE CAREFUL: You would begin counting on the *note given* and NOT the line or space above it. THIS IS THE MOST OFTEN MADE MISTAKE!!! (See example below)

This is an EXAMPLE of how you would follow the procedure.

You would be given the following: Build an Augmented *4*th up from the given note.

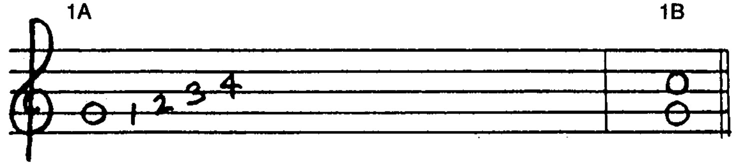


You would do
the following:

CORRECT EXAMPLE

STEP 1A: You would COUNT UP *4* lines and spaces.
STEP 1B: You would write in the note.

1A 1B



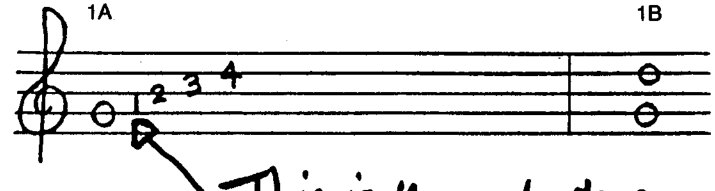
In this example, you now know that the correct interval will be a form of the note C, you may go on to STEP 2.

Do NOT turn the page until the proctor tells you to do so.

THIS IS THE MOST OFTEN MADE MISTAKE

FIGURE OUT WHAT'S BEEN DONE INCORRECTLY

1A 1B



This is the most often made mistake
You must start counting on the given note!

STEP 2A: To locate the exact interval, you would again begin on the given note, but in this step you would *COUNT UP* the number of *1/2 steps* between the given note and the note requested. To make this easier, we have included a Common Interval Chart (slip out of the next page) to help you correctly identify the numer of 1/2 steps for each interval.

STEP 2B: You would write in the correct sharp or double sharp, or flat or double flat if needed, as only correct spellings of the interval (not enharmonic spellings, which are, for example: writing a B for a C♭; or writing a G for a F##) are acceptable. When counting, it is important to remember that the distance between the notes *E and F* and *B and C* are 1/2 steps.

BE CAREFUL: If the note given is a sharp or flat, you would begin counting on that *specific* note and not the natural note. THIS IS THE MOST OFTEN MADE MISTAKE!!! (See example below)

In this example, you now know that the correct interval will be a form of the note C, you may go on to STEP 2.

Do NOT turn the page until the proctor tells you to do so.

This is the most often made mistake
You must start counting on the given note!

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BE CAREFUL: If the note given is a sharp or flat, you would begin counting on that *specific* note and not the natural note. THIS IS THE MOST OFTEN MADE MISTAKE!!! (See example below)

SAME EXAMPLE CONTINUED

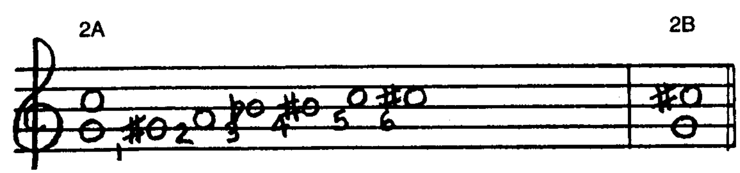
You would be given the following: Build an *Augmented* 4th up from the given note.

You would do
the following:

CORRECT EXAMPLE

STEP 2A: On the Common Interval Chart, you would locate the number *6* as the correct number of 1/2 steps for an *Augmented* 4th.

STEP 2B: You would write in the correct sharp or double sharp, or flat or double flat if needed.

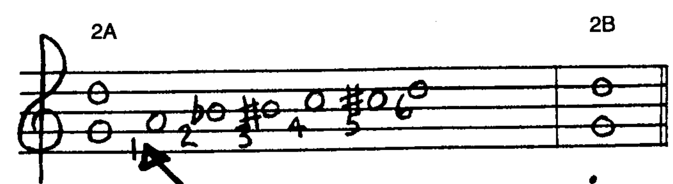


Now if you are uncertain about *any* of the steps of the procedure, go back and review before going on to the examples.

Do NOT turn the page until the proctor tells you to do so.

THIS IS THE MOST OFTEN MADE MISTAKE

FIGURE OUT WHAT'S BEEN DONE INCORRECTLY



No! Start on the specific note and count every 1/2 step!

FIGURE 1
Procedure from GceEce Booklet

not practice of the procedure; its purpose was to make sure that the students had read the example form of the common error.

Below is a chart of the common intervals within an octave. It will be useful for completing STEP 2 of the procedure. Use it to correctly identify the number of 1/2 steps for each interval requested. The specific interval names are listed in the left column, and in the right column the correct number of 1/2 steps is provided for each interval.

Specific Interval	*Number of 1/2 Steps*
minor 2nd	1
Major 2nd	2
minor 3rd	3
Major 3rd	4
Perfect 4th	5
Augmented 4th or diminished 5th	6
Perfect 5th	7
minor 6th or Augmented 5th	8
Major 6th	9
minor 7th	10
Major 7th	11
Octave	12

FIGURE 2
Common Interval Chart

Tests and Measures

A 14-item prerequisites test was given to ensure that the students possessed the necessary musical notation skills to learn the task. The results were not used as a covariate but as a screening device to eliminate the students who did not possess the skills to complete the task.

A five-question pretest was given along with the prerequisites test. The items were chosen from a pool of instances that were stratified (easy, medium, difficult, very difficult) on the basis of pilot test results and teacher experience, with one item selected at random from each of the easy, medium, and very difficult pools and two items selected at random from the difficult pool. Since it was proposed that a bimodal distribution of the results would occur (students can perform or cannot perform), five questions were felt to be sufficient to determine the possession of prior knowledge. A bimodal distribution did, in fact, result: the most frequent scores on the pretest were 0 and 5 (27 and 28 students, respectively, out of a total *N* of 141 students). Only 12 students had a score of 3. The results of the pretest were used as a covariate in analyzing the data.

The posttest contained ten questions which were chosen from the same stratified

Common Error in Generality Form

Common Error in Example Form	ABSENT	PRESENT
ABSENT	Control	Gen.
PRESENT	Examp.	Gen-Examp.

Control: group that received No common errors.
Gen: group that received the common error in the Generality form only
Examp: group that received the common error in the Example form only
Gen-Examp: group that received the common error in both the Generality and Example forms

FIGURE 3
Treatment Groups

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TABLE 1
Raw Means for Prereq

Control
General
Examp.
Gen-Examp.
Gen-Absent
Gen-Present
Examp-Absent
Examp-Present

pool, with two items randomly selected from each of the easy and very difficult pools, and three items randomly selected from each of the medium and difficult pools.

In both the pretest and posttest, students were simply given previously unencountered instances and were asked to "build a specific interval up from the given note."

To test the internal reliability of the posttest items, the Kuder-Richardson Formula 21 was used, which is for use when the examination is given only once or when the examination contains a small number of items (Borg & Gall, 1979). The result indicated a reliability coefficient of $r = .75$.

Procedure

Students were asked to participate in the study, and no student refused. All of the students completed the study during approximately 35 minutes of regular class time on either September 10, 11, or 12, 1984. No payment or grade was given for participating in the study. However, immediately prior to the administration of the study, students were encouraged to do their best, and the introduction page read: "Try to do your best because you will need to master this information in music theory, and it will also be useful in the further development of your musical knowledge." Students were also told not to turn the pages of the booklet until the proctor told them to do so.

Four forms of the instruction and all tests (on the same number of pages for each group) were randomly distributed to the students. All of the proctors read identical written instructions that included instructions concerning the page turning. The proctors gave no instructions concerning the task. The students were instructed to read each booklet page carefully and to wait for the cue to turn each page. Equal time on each page of the instruction was given for all groups and unlimited time was provided for the prerequisites test, pretest, and posttest.

All of the students were requested to complete the 10-question posttest at the end of the instruction booklet. They were allowed to use the Common Interval Chart (see Figure 2), but were not allowed to turn back to the instruction or examples. The posttest was printed on yellow paper, whereas the instruction and examples were on white, so the proctors could easily identify students who attempted to review the instruction. No proctor observed any attempts to review.

RESULTS

Although 141 students participated in the study, only 111 responses were considered usable. It was decided to exclude the results of those students who did not score at least 11 correct answers out of 14 questions (78.5%) on the prerequisites test, and those who scored 5 correct answers out of 5 questions (100%) on the pretest. The raw mean scores on the prerequisites test, pretest, and posttest for the four groups and the two main effects are listed in Table 1. These scores represent students' scores on the

TABLE 1
Raw Means for Prerequisite Test, Pretest, and Posttest (N = 111)

	N	*Prerequisite*	*Pretest*	*Posttest*
Control	27	13.2	1.81	5.74
General	26	13.2	2.08	6.58
Examp.	25	13.4	2.12	5.80
Gen-Examp.	33	12.9	1.42	6.09
Gen-Absent	52	13.3	1.96	5.77
Gen-Present	59	13.0	1.71	6.31
Examp-Absent	53	13.2	1.94	6.15
Examp-Present	58	13.1	1.72	5.97

TABLE 2
Adjusted Statistics for the ANCOVA Analysis of Posttest Scores

Effect	*Mean (SD) and* n *for Each Group*				*d.f.*	*F*	*p*
Gen	ABSENT 5.7 (.33) 52		PRESENT 6.56 (.30) 59		1,103	3.96	.049
Examp.	ABSENT 6.1 (.32) 53		PRESENT 6.15 (.31) 58		1,103	.01	>.1
Gen × Examp.	ABSENT-ABSENT 5.8 (.45) 27	ABSENT-PRESENT 5.57 (.46) 25	PRESENT-ABSENT 6.40 (.45) 26	PRESENT-PRESENT 6.72 (.41) 33	1,103	.41	>.1

three tests without adjusting for the pretest scores.

The unequal cell sizes should be noted. At Syracuse University, it was anticipated that 28 students would enroll in freshman music theory. However, 41 students enrolled in the course. In order to accommodate the additional students, the instructor decided, without consulting the investigators, to arbitrarily choose two forms of the booklet, reproduce them, and give them to the additional 13 students. The two booklet forms chosen were the Control version and the Gen-Examp version.

Since the attention-focusing devices for this study were handwritten in red, the nine usable reproduced booklets did not include the color enhancement. An F-test (one-way with two levels: with and without color) was performed on the posttest mean scores of each of the two groups (Control and Gen-Examp) from Syracuse University that received the mixture of original booklets and reproduced booklets. The results of the F-test were $F(1,6) = .03$, $p = .86$ for the Control group, and $F(1,10) = .04$, $p = .85$ for the Gen-Examp group, indicating that the reproduced booklets ($n = 9$) were not significantly different from the originals ($n = 102$). Consequently, it was decided to include the reproduced booklet scores in the study ($n = 111$).

Upon examining the pretest means, it appeared that the Gen-Examp group possessed less initial knowledge of the task (their raw mean score was 67% of that of the Examp group). To reduce the within-group variation and to eliminate prior knowledge as a confounding variable, the pretest was used as a covariate in the 2 × 2 analysis. Results indicated a significant correlation between the scores on the pretest and posttest ($F = 1.28$, $p = .0001$). Furthermore, a test for homogeneity of slopes was performed to make certain that there was no interaction between the covariate (pretest scores) and either of the two independent variables. Results indicated no significant interaction.

Table 2 lists the adjusted statistics for the ANCOVA analysis of the posttest scores. A significant difference did appear between the adjusted mean scores on the main effect for the common error in generality form (the Gen and Gen-Examp groups versus the Control and Examp groups), with the groups with the common error present in generality form performing better ($F = 3.96$, $p < .05$).

DISCUSSION

Hypothesis number one, which proposed that students receiving the presentation of the common errors in the generality form would perform significantly better than those who did not, was supported by the results. The second hypothesis, which proposed that students receiving the presentation of the common errors in the example form would perform significantly better than students who did not, was not supported by the results. Therefore, the findings of this study are:

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d.f.	F	p
1,103	3.96	.049
1,103	.01	> .1
1,103	.41	> .1

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1. The presentation of common errors in generality form significantly improves learning to perform a procedure at the application level.
2. The use of common errors in the example form appears not to be beneficial to the learner, even when matched with the correct performance and when attention-focusing devices are employed on the common errors.

These findings support and extend the findings of the Bentti et al. (1983) study, which concluded that (1) the presentation of common errors of the greatest divergence is beneficial, (2) common errors should be ones that are indeed commonly made, and (3) the presentation of a common error is most valuable when the error is clearly identified as such through various attention-focusing devices.

Contrary to the results of studies on matched nonexamples for concept attainment, it appears that the use of common errors in the example form is not useful in teaching a procedure. Hence, it also appears that the speculations of Ali (1981), Merrill (1983), and Gropper (1983) on the use of nonexamples for teaching a procedure at the use-a-generality level of performance were incorrect, for they (with the possible exception of Gropper) advocated the use of common errors in the example form, not the generality form. However, because this is the only study that has identified the form in which the common errors should be used, more research is required to confirm these tentative conclusions.

Furthermore, as with most instructional variables, it appears that it is easier to detect the effects of common errors when an attempt is made to control the amount of student effort spent on the learning. Humans are adaptive learners who will exert as much effort to learn as they feel is necessary, given their individual motivations. Students who want to understand the material usually will continue to exert effort until they feel they have mastered it. Therefore, if one treatment is worse than another, the difference in the effects of the treatments will be "absorbed" to a considerable extent by students spending more time and effort on learning than the students in the other treatment, but in both cases the average level of learning is likely to end up about the same. Controlling student effort, although not typical of most instructional situations, is not likely to produce an artificial result so much as to make the effects of the independent variable(s) impact more strongly on the dependent variable by reducing the "shock-absorber" effect of variations in student effort. This study and the Bentti et al. (1983) study both attempted to hold student effort constant across groups. The two studies which made no such attempt found no significant differences.

It should be noted that there is clear evidence that younger learners benefit relatively more from examples and less from generalities in their instruction. Therefore, the following instructional prescriptions are offered for the inclusion of common errors in instruction on procedures at the use-a-generality level for learners in the "formal operations" stage of intellectual development:

1. Include common errors in the generality form.
2. Clearly identify the common errors as *errors*.
3. Make certain that the errors included are errors commonly made.

These results will likely not generalize to younger learners.

Piaget and others suggest that there are three stages of intellectual development that are categorized by the child's use of his or her environment (Bruner, 1960). In the "pre-operational" stage (pre-school age) and the "concrete operations" stage (early school-age), common errors in example form might be more effective than in generality form. In the "formal operations" stage, the inclusion of common errors in generality form appears to be more useful.

It appears safe to say that the central research question concerning common errors for procedure learning is not whether common errors make a difference but *when* and in *what form* they make the biggest difference. Additional research is recommended to determine the value of teaching common errors in both forms to different age groups. Also, it seems possible that common errors may be detrimental for rote learning, where exposure to the error may actually increase the probability of the student making the erroneous response, as many behaviorists have claimed in their advocacy of error-free learning. On the other hand, if an error is meaningfully understood for a procedure that is learned meaningfully, such exposure to the common error seems likely to help the student avoid making that error. Research could also be done to compare the cost effectiveness of this approach with that advocated by Brown and Burton (1978), which is to wait until errors are committed before "debugging" them.

When attempting to replicate or extend this study, it is recommended that particular attention be given to the accurate identification of the errors *most commonly made*, and that attempts be made to control for student effort.

Researchers have also given little attention to the use of common errors in teaching principles (i.e., cause-and-effect relationships) but our intuition tells us they might not be as useful here. Nevertheless, this is also an area worthy of future research.

This study is but one step in exploring the possibility that presenting common errors (nonexamples) will improve the effectiveness of instruction on use-a-generality objectives. It is hoped that the findings offer useful information that will contribute to further research efforts.

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