Analogies, Explanations, and Practice: Examining how task types affect second language grammar learning

Ruth Wylie[1], Kenneth Koedinger[1], and Teruko Mitamura[2],

[1] Human-Computer Interaction Institute, [2]Language Technologies Institute
Carnegie Mellon University, 5000 Forbes Avenue
Pittsburgh, Pennsylvania 15213 USA
{rwylie, krk, teruko}@cs.cmu.edu

Abstract. Self-explanation is an effective instructional strategy for improving problem solving in math and science domains. However, our previous studies, within the domain of second language grammar learning, show self-explanation to be no more effective than simple practice; perhaps the metalinguistic challenges involved in explaining using one's non-native language are hampering the potential benefits. An alternative strategy is tutoring using analogical comparisons, which reduces language difficulties while continuing to encourage feature focusing and deep processing. In this paper, we investigate adult English language learners learning the English article system (e.g. the difference between "*a* dog" and "*the* dog"). We present the results of a classroom-based study (N=99) that compares practice-only to two conditions that facilitate deep processing: self-explanation with practice and analogy with practice. Results show that students in all conditions benefit from the instruction. However, students in the practice-only condition complete the instruction in significantly less time leading to greater learning efficiency. Possible explanations regarding the differences between language and science learning are discussed.

Keywords: Intelligent Tutoring Systems, Self-Explanation, Analogical Comparisons, Second Language Learning

1 Introduction

Many studies have shown self-explanation to be an effective instructional strategy [1, 2, 3]. Early work by Chi and colleagues [4] showed that students who spontaneously self-explain more, learn more. Later studies showed that students who are prompted to self-explain learn more than those who are not prompted [1], and finally, Aleven and Koedinger's work reveals that the advantages of self-explanation prompts persist even when students do not generate the self-explanation on their own but instead are asked to select the general principle from a menu [2]. Roy and Chi [5] propose that the benefits of self-explanation are due to increased involvement in the learning process, and that as a result of self-explaining, students focus on the meaningful aspects of the material.

While self-explanation shows great promise in increasing learning, most studies have dealt with math and science domains and relatively little work has been done in areas like second language learning. In a previous study, we investigated the effects of adding self-explanation prompts to an English as a Second Language (ESL) grammar tutor used to teach the English article system (i.e. teaching students when to use “a”, “an”, “the”, or no article). Results showed that while prompting for self-explanations lead to significant learning gains, there was not a clear advantage for self-explaining over simple practice where students did fill-in-the-blank tasks (choosing the best article to complete the sentence) without prompts to self-explain [6]. One reason could lie in the metalinguistic challenges that students face when doing self-explanation in their non-native language. For example, many of the article rules contain challenging and domain-specific vocabulary that may be difficult for a non-native speaker (e.g. “Use ‘a’ when the noun is general, singular, and begins with a consonant sound.”) Thus, we began to look for other instructional strategies that encourage deep processing without the extraneous, metalinguistic challenges.

One candidate is analogical comparison. In a typical analogical comparison problem, students are presented with two worked examples and asked to compare the similarities and differences between them. Analogical comparisons reduce the metalinguistic demands compared to prompted self-explanation (i.e. in the analogy problems, students don’t have to tackle domain-specific vocabulary words like “consonant”), and multiple comparisons provide the added advantage of presenting students with more examples of correct article use, which alone may be beneficial for language learning [10]. The assumption behind analogical comparisons is that by comparing the examples, students will be able to extrapolate the underlying schema of the two problems [7]. Like self-explanation, analogy training has proven to be successful for a variety of domains and learners. In a study investigating business negotiation training, Gentner, et al. [8] found students who were instructed using analogical encoding produced better written solutions on posttest items and were able to transfer their skills to the more challenging modality of face-to-face negotiation. While much of the existing work has looked at students’ mapping schemas from a well-understood example to a novel one, there is also evidence that students benefit when the two examples are only partially understood [9].

In this work, we explore the effects of using strategies that encourage deep processing of the material on students’ learning in the challenging domain of the English article system. We begin by describing three problem types (practice, self-explanation, and analogical comparison). Using these activities, we created three computer-based tutoring conditions (practice-only, self-explanation with practice, and analogical comparison with practice) and evaluated their effects on knowledge acquisition and learning efficiency in a controlled classroom study.

2 Problem Types

This study employed three types of tutored problems: practice, self-explanation, and analogical comparison. For the *practice* problems (Figure 1), students were given a sentence and chose the article (*a, an, the*, or no article) that best completed the sentence. For the *self-explanation* problems (Figure 2), students were presented with a sentence with the target article highlighted and chose the rule or reason driving the article decision (e.g. “the noun has already been mentioned” or “the noun is general and non-count”). For each self-explanation problem, students chose from a menu of six rules, always presented in the same order. The order was kept constant to reduce the search time students needed to select their answers. In order to align the tutors with previous classroom instruction, we used the same vocabulary that was used in the students’ textbooks [11]. Similarly, for the *analogical comparison* problems (Figure 3), students were given a sentence with the target article highlighted and chose the analogous sentence that used the same article rule as the given sentence. For example, given the sentence, *Last week, I bought a car. Today,* ***the*** *car broke*, students should choose the sentence *Sally found a dog, and* ***the*** *dog is small and black* since both the given and analogous sentences use the rule that if a noun has already been mentioned then “the” is used. There was one analogous sentence for each of the six article rules covered in the material. In an attempt to prevent students from developing spurious associations, all the analogous sentences were approximately equal in length and used similar vocabulary. In addition, the analogous sentences used simple vocabulary and were easy to read (Flesch-Kincaid Grade Level = 2.0). The same six analogous sentences were presented in the same order for each of the analogy problems.

During the instruction phase, students received immediate feedback on their selections (the answer turned green if it was right, red if it was wrong) and had access to on-demand hints. The tutors were developed in Flash using the Cognitive Tutor Authoring Tools [12] and deployed via the web. All student actions were logged and time-stamped.

2.1 Tutoring Conditions

Three corresponding experimental conditions were created using the above task types: practice-only, self-explanation with practice, and analogy with practice. Students in all conditions received 30 identical practice problems. In addition, students in each condition received 30 condition-dependent items: students in the self-explanation with practice condition received 30 self-explanation problems, students in the analogy with practice condition received 30 analogy problems, and students in the practice-only condition received 30 additional practice problems.

Previous research has shown the benefits of interleaving examples with problem-solving practice [13] and that learning from examples is more beneficial during early rather than later stages of skill acquisition [14]; therefore, we had students in the self-explanation with practice and analogy with practice conditions do more condition dependent items in the beginning and then move to interleaved blocks of matched practice and condition dependent problems, and finally, end with practice problems. More specifically, in the self-explanation with practice condition, the first ten problems were self-explanation problems; the next forty problems consisted of alternating blocks of five practice problems and five explanation problems, and finally, students completed ten practice problems. The analogy and practice condition used the same structure but students did analogy problems in place of the self-explanation items (Table 1).

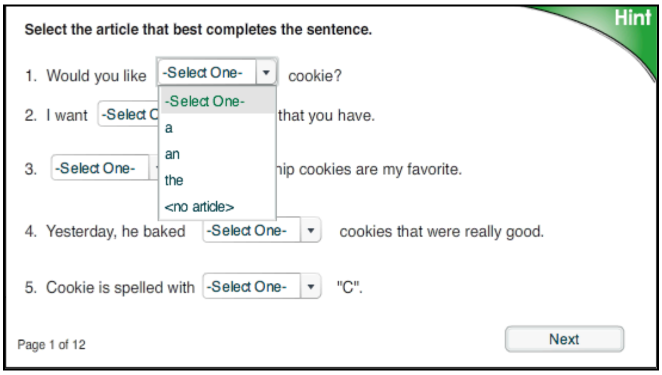


Fig. 1. Example practice problems. In the practice problems, students select the article that best completes the sentence.

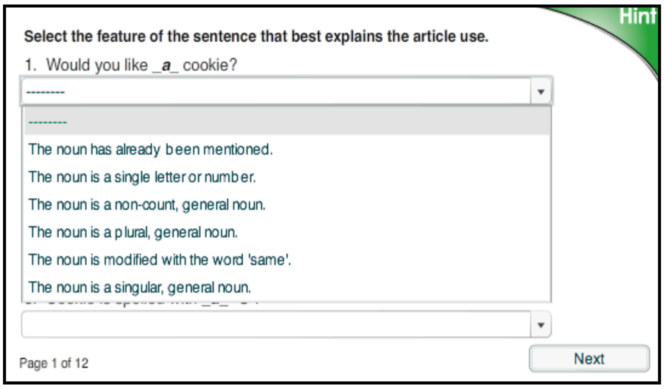


Fig. 2. Example Self-Explanation Problems. In the explanation problems, students select the rule or feature of the sentence that best explains the article use.

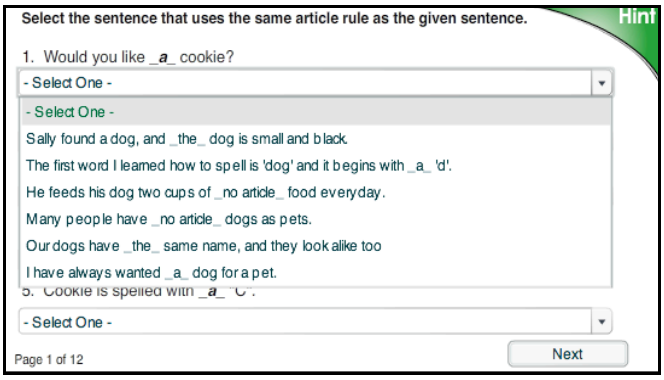


Fig. 3. Example Analogy Problems. In the analogy problems, students select the example sentence that uses the same rule as the given sentence.

Table 1. Sequence of problem type by condition. Students in the practice-only condition completed sixty practice items, while students in the analogy and practice and explanation and practice conditions also completed sixty items, alternating between blocks of practice and analogy or explanation items.

Item #	Practice-only	Analogy and Practice	Explanation and Practice
1-5	Practice	Analogy	Explanation
6-10		Analogy	Explanation
11-15		Practice	Practice
16-20		Analogy	Explanation
21-25		Practice	Practice
26-30		Analogy	Explanation
31-35		Practice	Practice
36-40		Analogy	Explanation
41-45		Practice	Practice
46-50		Analogy	Explanation
51-55		Practice	Practice
56-60		Practice	Practice

We controlled for several factors in the design of the three conditions: all condition used the same sixty target sentences, presented in the same order, and the hints presented the same information, although in slightly different forms. For the practice problems, the features of the sentence important for choosing which article to use were presented in the first hint; next, students were given the complete rule, and finally, students were told which article to select. When completing the explanation problems, students were first presented with the important features of the sentence, and then told which explanation to choose. Finally, for the analogy problems, students first saw the important features; second, they were given the example sentence that contained the same feature; and, finally, told which example sentence to select.

3 Classroom Evaluation

To evaluate the effectiveness of the three tutoring conditions in a real-life setting, a classroom study was conducted at the University of Pittsburgh's English Language Institute. Students (*N*=99) were adult English language learners (mean age = 27.9, SD=6.6) and participated as part of their regular grammar class. Data collection was completed within one 50-minute class period. Genders were equally represented, and students came from a variety of first language backgrounds, which were equally distributed across conditions ($\chi^2(2, N=99) = 27.2, p = 0.71$). After a brief introduction to the tutoring systems, students completed a computer-based pretest and were randomly assigned to a tutoring condition: practice-only (n=33), analogy with practice (n=34), or self-explanation with practice (n=32). Students completed the posttest, which was isomorphic to the pretest, immediately after finishing the tutoring. Pre and posttest items were identical in form to the practice problems students saw during tutoring (i.e. students chose the article that best completed the sentence). However, while taking the tests, students did not receive feedback on their selections and did not have access to hints.

3.1 Hypotheses

In our study, we were primarily concerned with two metrics: learning gains and instructional time. We hypothesize that students in the analogical comparison with practice condition will demonstrate greater learning gains than those in the practice-only condition due to increased engagement and deeper processing of the material. In addition, we expect students in the analogy with practice condition to show greater gains than those in the self-explanation condition due to the reduced linguistic demands of analogies compared to self-explanations *(H1)*. Namely, we believe that the concepts governing ESL article usage will be acquired more easily implicitly (i.e. through analogies) than explicitly (i.e. through rules and self-explanation).

While our main goal is to increase student performance, given the limited amount of classroom time available, it is also important that the instruction be efficient. We hypothesize that students in the practice-only condition will complete the instruction faster than those in the other conditions *(H2)*. When making article selections (versus choosing explanations or analogies), students only have four options from which to choose (*a, an, the*, or no article), fewer words to read, and practice alone may be less cognitively challenging than explaining or choosing analogies.

3.2 Results

In *H1*, we hypothesized that the analogy with practice condition would lead to greater learning gains compared to the other conditions. Results of a repeated measures analysis of variance (ANOVA) with test score as the dependent measure, test time (pretest and posttest) as a within-subject factor, and tutoring condition as a between-subject factor reveals a significant main effect for test time ($F(1,96) = 63.6$, $p < 0.001$) but no interaction of test time by condition ($F(2, 96)=1.30$, $p = 0.28$). Students, regardless of condition, demonstrate significant learning gains (Figure 4).

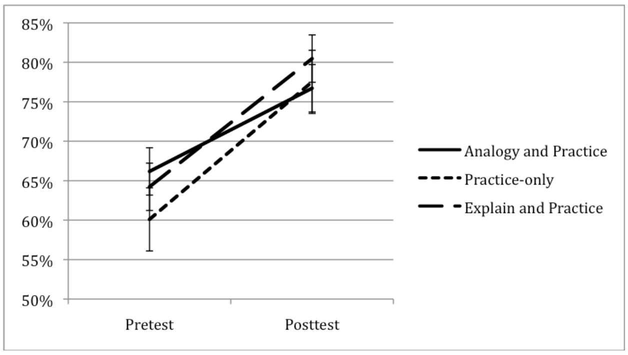


Fig. 4. Students in all three conditions show significant pre to posttest learning gains.

H2 stated that students in the practice-only condition would complete the instruction faster than those in the analogy with practice and self-explanation with practice conditions, and timing results support this hypothesis. An ANOVA with total time spent using the tutor as the dependent variable reveals a significant effect of condition (F (2, 96) = 6.44, p = 0.002). Post-hoc Tukey HSD tests reveal that students in the practice-only condition complete the instruction the fastest (M=13.4 minutes, SD=4.3) and significantly faster than those in the analogy with practice condition (p=0.045, M=17.0 minutes, SD=7.5) and the self-explanation with practice condition (p=0.002, M=18.6, SD=6.0). No significant difference was found between the time-on-task of students in the two deep-processing conditions. However, a closer analysis of the timing data reveals a more nuanced result. We used a MANOVA with condition as the independent variable and time to complete the identical practice problems and condition dependent problems as the dependent variables. These results revealed that students in the practice-only and analogy with practice conditions completed the identical practice problems in the same amount of time (practice-only M=6.14, SD=18.8, analogy M=6.18, SD=2.06, p=0.99) and significantly faster than students in the self- explanation with practice condition (M=7.87, SD=2.29, Tukey HSD p=0.003). For the condition-dependent items, students in the practice-only condition completed their items the fastest (M=7.21, SD=2.58) and significantly faster than the analogy with practice (M=10.78, SD=5.89, p = 0.004) and self-explanation with practice conditions (M=10.78, SD=4.08, p = 0.004) (Figure 5).

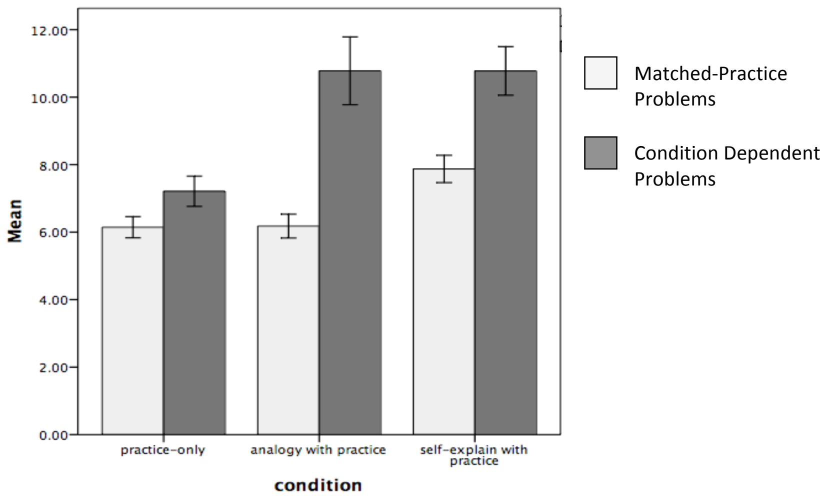


Fig. 5. Breakdown of tutor time by problem type. Students in both the practice-only and analogy with practice conditions completed the identical practice problems faster than students in the self-explain with practice condition. In addition, students in the practice-only condition completed the condition dependent items significantly faster than students in both the analogy with practice and self-explanation with practice conditions.

We also looked at how much instructional support (e.g. hint requests, incorrect steps, etc.) students used while completing the instruction. Hypothetically, students in one condition might request more hints or make more incorrect selections, actions that would increase the amount of time it takes for the task to be completed. Similarly, some tasks may be more prone to gaming (e.g. systematically going through the menu choices in order to get the correct answer [15]), resulting in smaller learning gains. To address these issues, we looked at the frequency of hint requests and incorrect answer choices. On average students requested hints on only 6.7% of the problems (SD=10.5), and an ANOVA showed no significant differences between conditions ($F_{(2,96)}=0.560$, $p = 0.573$). With respect to errors, overall, students made an incorrect selection on 26.1% of the problems (SD=16.3), and again there were no differences between conditions ($F_{(2,96)} = 1.32$, $p = 0.27$).

3 Discussion

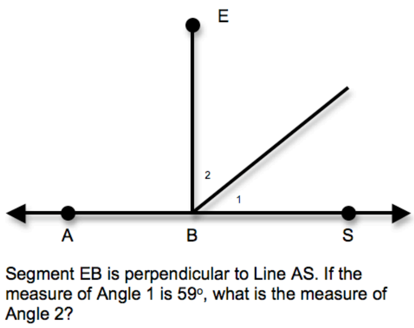
This study addressed the issue of which instructional strategy (practice-only, analogy with practice, or self-explanation with practice) is best for learning the English article system. The results show that students in all conditions make significant learning gains but that practice-only is more efficient than self-explanation and analogical comparisons. Students in the practice-only condition learned as much as those in the other conditions but required significantly less time to complete the instruction. Furthermore, since there were no differences among conditions with respect to instructional support (e.g. number of hints requested, amount of incorrect feedback received), the greater efficiency is not due to students in one condition spending more time reading hints or gaming the system. These results suggest that the extra time it takes students to choose the explanation or analogous sentence is not beneficial.

One way to explain these results is to examine the knowledge type (explicit vs. implicit) and instructional approach (deep processing vs. no deep processing) for each of the tutoring conditions (Table 2). First, it is important to note that all conditions were equally beneficial when looking at learning gains alone, suggesting that both types of knowledge and instructional strategies are beneficial for learning. However, the differences between the conditions become more prevalent when looking at the timing data. Table 2 suggests an explanation for the timing difference between the condition-dependent problems. Again, the condition dependent problems used the same sentence stimuli but differed in the task students performed. Results show that deep processing of the material (e.g. self-explanation or analogy selection) requires more time than simple problem solving. Further, since learning gains are constant across conditions, it does not seem that the added time required to deeply process the material is beneficial for the students. In addition, timing data from the identical practice problems (problems that all students, regardless of condition, completed) show that students in the analogy with practice and practice-only conditions complete these problems significantly faster than students in the self-explanation with practice condition. Again, Table 2 suggests why this difference occurs; namely, while students in the analogy with practice and practice-only conditions are using implicit knowledge; students in the self-explanation with practice condition are relying on explicit knowledge to make their article selections. The process of retrieving explicit knowledge is more time consuming using implicit knowledge to complete the problems.

Table 2. Classification of tutoring condition by knowledge type and instructional approach.

	Deep Processing	No Deep Processing
Implicit Knowledge	Analogy	Practice
Explicit Knowledge	Self-Explanation	

One open question is why do these results differ from the many studies that show an advantage for self-explanation and analogical comparisons; what makes second language grammar learning different? We propose that it is not the domains that are driving these differences but the number of mental steps required to solve the problem. For example, a typical geometry problem may include a diagram and ask students to calculate the value of an unknown angle. To successfully solve this problem, students need to develop and execute a rather complicated plan (Figure 6). However, a typical English article problem (e.g. *Yesterday, I bought new shoes. ___ shoes are red.*) requires fewer steps: (1) Set goal to choose the article. (2) Select (either implicitly or explicitly) the correct rule (*If a noun has already been mentioned, use the*), and (3) apply it (*Yesterday, I bought new shoes. <u>The</u> shoes are red*). We believe that the understanding acquired through deep processing scaffolds the generation of a correct knowledge application plan. When this plan involves many mental steps, as in often the case in math and science, this scaffolding is necessary and helpful. However, when the knowledge application plan is short, the benefits of deep processing decrease. Future research should empirically investigate this argument by conducting a 2x2 experiment which examines the effects of deep processing instructional manipulations on math and language problems with both short and long solution plans.



Knowledge Application Plan

1. Set a goal to Find Angle 2.
2. Retrieve Rule: Lines that are perpendicular intersect at 90° angles, therefore Angle 1 + Angle 2 = 90°
3. Substitute given value: 59° + Angle 2 = 90°
4. Solve for Angle 2.
5. 90° – 59° = Angle 2
6. Angle 2 = 31°
7. Enter the result: Angle 2 = 31°

Fig 6. Example of a typical geometry problem that requires several mental steps to solve.

In conclusion, this work suggests that repeated practice is more efficient for learning the English article domain than self-explanation with practice or analogical comparisons with practice. It provides a possible explanation for why these findings differ from much of the previous work. Future work plans to further investigate these differences in an attempt to establish boundary conditions for instructional strategies that foster effective processing of the material.

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