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Enhancing Student Learning Outcomes through Brief Cold Working and Annealing Interventions in Materials and Manufacturing Selection in Design Course

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Session XXXX

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Abstract

This study examines the impact of a brief (10-15 minute) annealing and cold working classroom intervention on student learning outcomes in the Materials and Manufacturing Selection in Design course. The intervention, designed to fit seamlessly into the course schedule, uses active learning strategies to help students describe the microstructural evolution and the corresponding effects on material properties during cold working, annealing, and phase transformations. Through short demonstrations and problem-solving activities, students observe how these processes influence material characteristics, enhancing both their conceptual understanding and ability to apply this knowledge. Results show that these brief, focused interventions significantly improve student engagement, retention, and learning outcomes in complex technical topics. This work extends prior research in materials science education[1], demonstrating the effectiveness of short, active learning strategies in reinforcing key learning objectives.

Introduction

Classroom demonstrations are a valuable tool for conveying concepts in challenging subjects. They help reinforce and stimulate students' learning[2,3,4] and increase their engagement. Interactive demonstrations have been shown to offer numerous benefits, including improved performance, development of independent learning skills, critical thinking, and problem-solving abilities. Adding demonstrations not only increases enjoyment but also positively impacts learning.

Students often exhibit misunderstandings or misconceptions regarding certain concepts[5,6,7]. To address this, we propose introducing short demonstrations and activities that can be easily implemented in typical lab or classroom settings. These experiential learning activities are designed to combat misconceptions, increase student engagement, enhance learning, and improve the retention of concepts[8]. Additionally, these activities serve as a tool to enhance critical thinking skills.

In designing these demonstrations, we reviewed the literature for best practice guidelines[9,10,11]. Miller et al. emphasized the importance of correctly observing a demonstration to achieve conceptual understanding[12]. They noted that a lack of learning or understanding can occur when experiments do not proceed as expected.

An essential element of an effective demonstration is allowing students to predict the outcome. In addition to this approach, we also reviewed the underlying physics and, where possible, included hands-on elements to actively engage students and make the demonstrations more interactive. Other elements we implemented included keeping the demonstrations short, attention-grabbing, and conducted in small groups. Using this framework, as depicted in Figure 1, a short demonstration intervention and activities were developed.

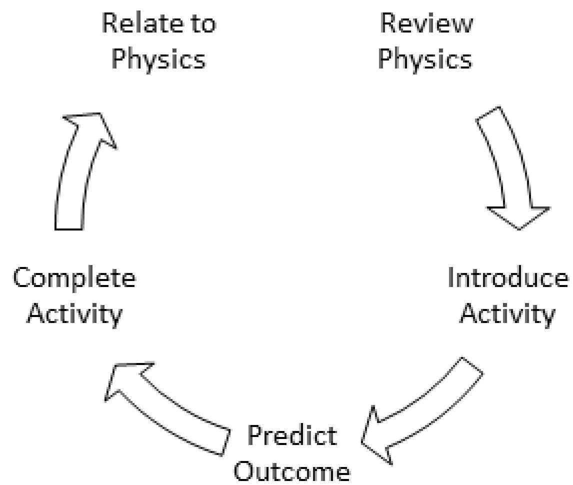


Figure 1. Proposed framework for implementation of demonstrations[13].

Intervention Preparation and Post Quiz

Eight sets of samples were prepared using the following procedure:

- Use annealed 360-brass. 12 bars
- Dimensions – 6 inches long, 1 inch wide and ¼ inch thick.
- Reduce thickness by 60% to approximately 8-10 inches
- Cut them into ½ inch wide pieces.
- Anneal 8 to 1100 °F for 90 minutes and furnace cool.
- Anneal 8 for 10 minutes at 1100F.
- Leave the remaining as is.

Figure 2 shows a set of samples that are color coded based on the cold working and annealing case. The samples were cleaned to make all look the same.

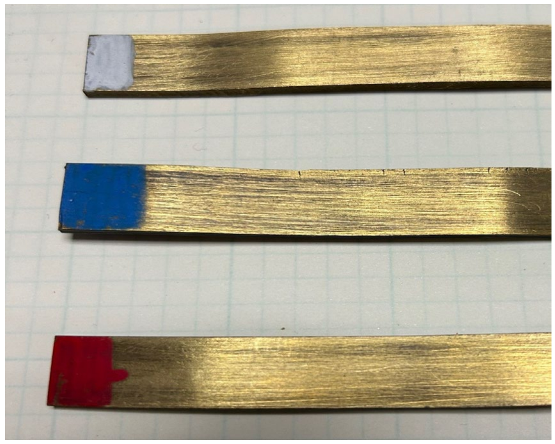
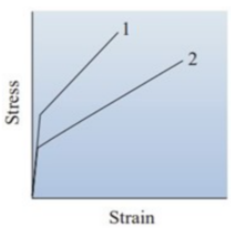


Figure 2. Color-coded Cold-worked and Annealed Samples, Red: fully annealed, Blue: annealed to 1100 °F for 90 minutes, and White: annealed to 1100 °F for 10 minutes.

These sets of samples are handed to student teams during the class. Teams are asked to identify which one was the cold worked, completely annealed, and partially annealed. Teams are asked to bend the specimens and get a "hands-on" feel of which would easier or harder to bend and justify why. This exercise takes around 5-10 minutes with class discussion and Q&A. The Baseline and Study groups are two sections of the same course taught by the same instructor having around 80 student each.

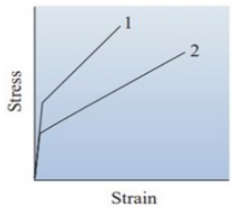
Table 1. Sample Quiz Questions for Both Study and Baseline Groups.

Samples 1 and 2 have the same composition and were processed identically, except that one of them was cold worked more than the other. The stress-strain curves were obtained after the samples were cold worked. Which sample has the higher recrystallization temperature: 1 or 2?



- Sample 1 has a higher recrystallization temperature.
- Sample 2 has a higher recrystallization temperature.
- Both samples the same recrystallization temperature
- I need more information to judge

Samples 1 and 2 have the same composition. Both were cold worked in the first stage. The figure represents the behavior after this stage. Which of the two samples represented by 1 and 2 can be cold rolled to a greater extent?



- Sample 1 can be cold rolled to a greater extent.
- Sample 2 can be cold rolled to a greater extent.
- Both samples can be cold rolled to a similar extent.
- I need more information to judge

Point Biserial Correlation Coefficients for both groups vary across questions, but all of these questions had positive values indicating good differentiators between the top 25%, lower 25%, and the rest of the students. Students were asked to justify their answers for these questions. This helped in propping their understanding and analyzing misconceptions they had a bout the topic.

Post Quiz Results

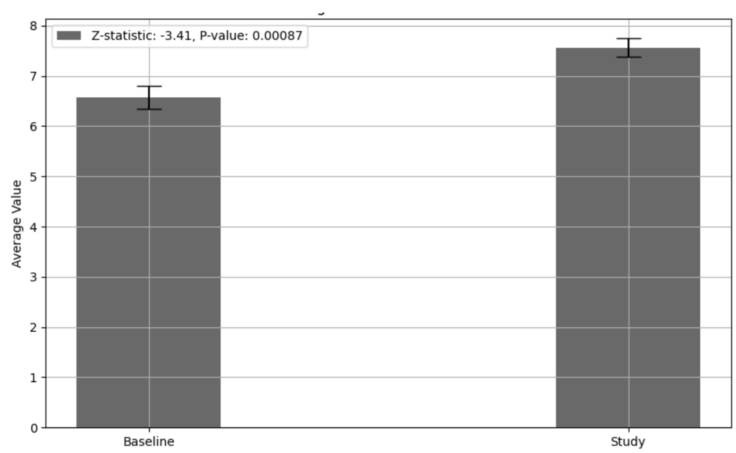


Figure 3. Comparison of Quiz Averages of Baseline and Study Groups.

The mean value of the Study group (7.56/10.00) is higher than that of the Baseline group (6.57/10.00), with both groups exhibiting relatively similar standard deviations. Figure 4 shows the distribution of the quiz results as a histogram for both baseline and study groups. The results of the study group showed clear improvement over that of the baseline. More students are getting higher correct answers and higher score values of the quiz. The natural distribution also reflects this. The statistical Z-test was performed where the p-value obtained is very small, less than the common significance level of 0.05, indicating a statistically significant difference between the Baseline and Study groups. This suggests that the intervention in the Study group had a significant effect compared to the Baseline group.

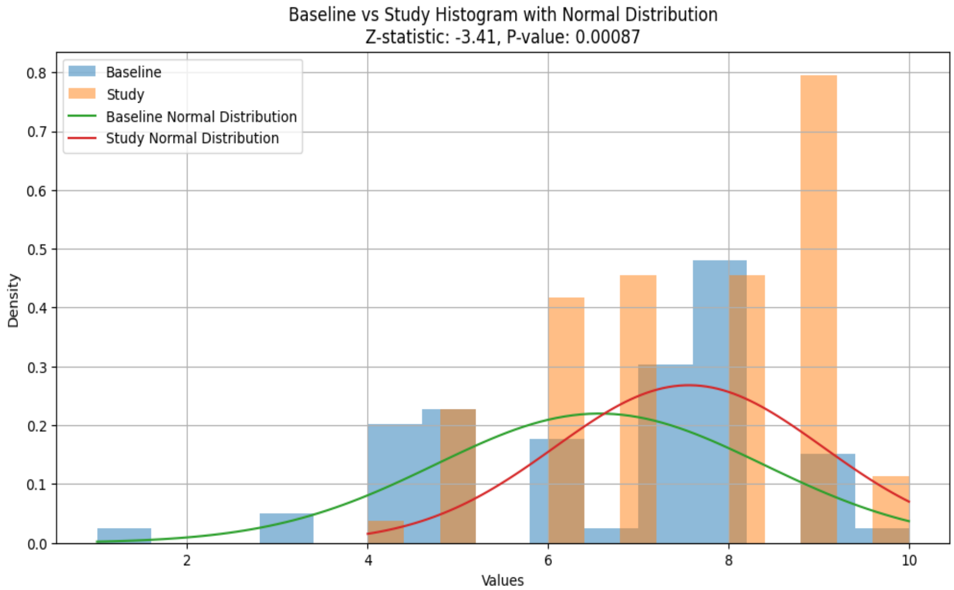


Figure 4. Histogram Comparisons of Baseline and Study Group.

Summary and Conclusions

Short class interventions do not consume a lot of class time but their impact on student learning outcome in the Materials and Manufacturing Selection in Design course were measured and showed a statistically significant improvement with more than 95% confidence. Students' engagement with a hands-on experience helped students understand hard concepts of cold working, annealing, temperature, and time and their impact on the physical material behavior.

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