Chapter 6
Print ISBN: 978-81-967636-3-3, eBook ISBN: 978-81-967636-2-6

Correlation of Hardware Demonstrations and Student Understanding

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DOI: 10.9734/bpi/taer/v1/1380G

Peer-Review History:
This chapter was reviewed by following the Advanced Open Peer Review policy. This chapter was thoroughly checked to prevent plagiarism. As per editorial policy, a minimum of two peer-reviewers reviewed the manuscript. After review and revision of the manuscript, the Book Editor approved the manuscript for final publication. Peer review comments, comments of the editor(s), etc. are available here: https://peerreviewarchive.com/review-history/1380G

ABSTRACT

This chapter aim to investigate the pedagogic effect of demonstration construction quality. The hypothesis that the construction finish of a classroom demonstration affects its pedagogic value will be assessed by constructing two different demonstrations: a remote controlled vehicle and a laser-based audio communication device. This study looks at two types of construction: "raw" and "polished." Raw demonstrations use prototype-quality construction techniques that include exposed solderless breadboards, whereas polished demos use production-quality construction techniques aimed to replicate conventional consumer electronics. The impact of the demonstrations on student interest was measured by creating paired pairs of demos of raw and polished quality. These were utilized in lectures to 119 students, and post-lecture surveys were conducted to gauge student interest and comprehension. Implementing only a single demonstration in both raw and polished forms, preliminary findings reveal that students in both technical and nontechnical majors score higher in objective assessment and report more interest in the topic when employing raw construction techniques (two-tailed p=0.051 and 0.01 respectively). The findings indicate that demonstrations are more valuable in their raw form.

Keywords: Demonstrations; demonstration construction; lecture aids; raw demonstrations; polished demonstrations; pedagogic effectiveness.

1. INTRODUCTION

The use of technology-aided education as a pedagogical method is not a modern phenomenon, and investigations into its utility have been studied for almost half a century. As far back as the 1970s, Ellinger and Frankland [1] found that the use

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of early computers to teach economic principles produced comparative learning outcomes with traditional didactic methods such as lectures [2,3,1]. It is commonly acknowledged that demonstrations promote pedagogical effectiveness in general [4–8] and motivation in particular [9]. Many studies, for example [10–14], show the positive benefits of specific demonstrations on student learning; nevertheless, little study has been done to discover what essential elements of demonstrations make them most pedagogically useful. We wanted to characterize demonstrations based on their construction finish quality and see how this parameter affected pedagogical utility.

This study, in particular, divides demonstration construction quality into two categories: "raw" and "polished." Raw demonstrations use prototype-quality construction techniques such as exposed solderless breadboards and knobs attached to angle-brackets, leaving wiring and through-hole components visible. Polished demonstrations use production-quality construction techniques such as CNC-machined front panels, with circuit boards hidden behind a lacquer-finished exterior. Based on anecdotal evidence, we hypothesize that technical majors such engineering and physics students prefer demonstrations that use raw construction methods, perhaps because it appeals to their sense that they could build the device themselves, and that liberal arts students prefer polished construction techniques, perhaps because they look similar to commercial consumer electronics products they use.

2. METHODS

The hypothesis that the construction finish of a classroom demonstration affects its pedagogic value will be assessed by constructing two different demonstrations: a remote controlled vehicle and a laser-based audio communication device. This works-in-progress paper reports the experimental findings of the remote controlled car only. The car was used with a ten-minute lecture describing the coil and damper in suspension systems. It was used in one of two configurations to demonstrate the raw and polished construction techniques (see Fig. 1) by either leaving the top chassis exposed or covering it with an injection-molded painted monster-truck body. The cover did not obscure the coil/damper struts so the car's potential efficiency as a demonstration for the lecture topic was unchanged.

Fig. 1. Examples of a "raw" and "polished" demonstration versions used for a coil-and-damper suspension system

Pedagogic efficiency was assessed with a five minute post-lecture questionnaire. The questionnaire recorded basic demographic information (academic major, class year), and asked several questions of progressive difficulty about the lecture material to objectively assess student comprehension. It also asked the students to self-rate the demonstration's impact on their understanding of the material and separately on their desire to learn more about the subject. Thus, three different metrics of the pedagogic efficiency of the demonstration were obtained: an objective comprehension score, the students' self-assessed subjective comprehension, and the students' subjective assessment of their enjoyment. All scores were normalized on a 0-1 range to simplify comparisons. Two-tailed Student T tests were used to determine whether construction quality affected the above three chosen metrics of pedagogic efficiency. Error bars in results refer to the experimental standard error of the mean.

3. RESULTS

The raw data is shown in Fig. 2. The type of construction exhibited a strong trend toward statistically significant impact upon objective comprehension scores with a two-tailed p of 0.053, and clearly influenced student enjoyment with a $p < 0.01$. Interestingly, by both measures the "raw" demonstrations were more effective than their "polished" counterpart. Demonstration quality did not appear to influence the students' self-assessment of their comprehension ($p>0.20$).

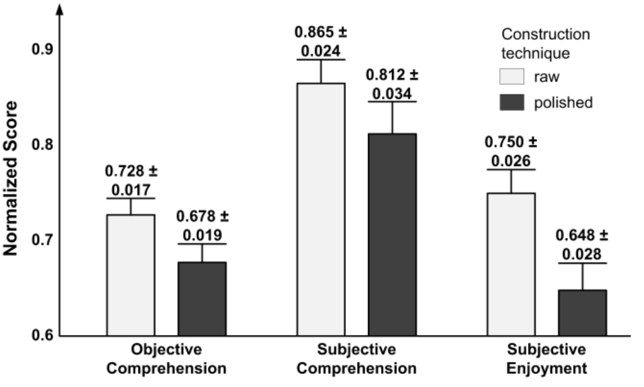

Fig. 2. Student responses to different types of construction techniques

Results grouped by major revealed grossly similar findings. Grouping did not alter trends, although smaller experimental subgroupings removed statistical significance from all measurements except non-technical majors ratings of enjoyment (Fig. 3). These showed they overwhelmingly preferred the "raw" demonstration quality ($p<0.01$). The fact that high statistical significance was achieved indicates that, at least for this particular demonstration, it is unlikely to be caused by the relatively small sample of N=24 and 33 for the polished and raw trials of non-technical majors, respectively. In particular, it shows the surprising result that students preferred the raw demonstrations to the polished ones – they learned better using them. This may be caused by the students' ability to understand how the raw demonstrations were constructed, which therefore help them understand the design principles that they infer. Interestingly, they enjoyed seeing the raw demonstrations more also, which may reflect the fact that they can imagine them building the demonstrations themselves.

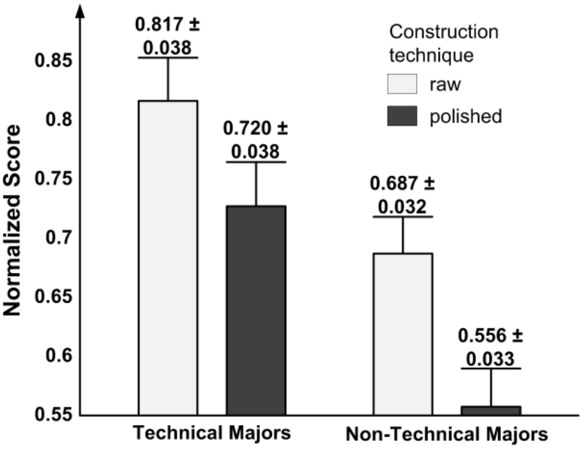

Fig. 3. Grouping subjective enjoyment scores of Fig. 1 by major

4. CONCLUSION

These preliminary results show the particular engineering-style demonstration used in this study is more effective, both as an instructional and motivational tool, when using prototype-quality construction techniques than when using commercial-quality polished construction techniques. These results hold regardless of student major.

By collecting additional data using other demonstration models we hope to determine if this finding can be generalized, and thus serve as guidance that when creating any engineering pedagogical demonstration, we should keep them looking like the prototypes they are.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX – QUESTIONNAIRE

1. What is your major field of study (e.g. biology, IS, English) and year (e.g. fresh/soph/junior/senior+)?

   Field_________________________ Year _________________________

2. How did the demonstration of the model car affect your interest in the subject matter
   a) The demo made me much more interested in the lecture material; I'm likely to find out more about suspension systems on my own time because of it.
   b) I found seeing the demo made me more interested in hearing the talk about suspension systems. Still, I doubt I'll be Googling to learn more about suspensions systems in the near future.
   c) The demo was interesting in itself but didn't make me want to learn about suspension systems, either in the talk or outside of class.
   d) The demo was lame and reinforced my opinion that I just wasted 10 minutes of my time.

3. How did the demonstration help you understand the subject matter?
   a) Having a chance to examine the demonstration clarified some things that I would probably not have understood from the lecture alone.
   b) Having a chance to examine the demonstration showed me that I correctly understood the material about springs and dampers taught in class but didn't help me learn anything new.
   c) The demo might be cool looking, but it didn't really help me understand anything about suspension systems.
   d) I honestly didn't bother to look at it much.

4. A car goes over a pothole and continues to bounce up and down for 15 seconds. The problem is
   a) Springs too strong
   b) Springs too weak
   c) Dampers too strong
   d) Dampers too weak
   e) There is no problem; this is normal behavior

5. A street car needs to have its suspension changed to make it competitive on a smooth race track. Its springs should be made
   a) harder
   b) remain unchanged
   c) softer

6. A new car design tends to bounce too quickly. What changes could be made to the dampers to fix this?
   a) make them easier to compress
   b) make them harder to compress

c) you can only change the speed that the car bounces by changing the springs, not the dampers.

7. A new car design tends to ride too “rough”, meaning on bad roads the passenger cab vibrates too much. What parts might need to be redesigned to fix this?
   a) The dampers and the springs. They are interrelated.
   b) Only the dampers. The springs do not affect ride roughness.
   c) Only the springs. The dampers do not affect ride roughness.

8. 8How would your car’s suspension feel if the springs snapped and fell apart?
   a) very hard since the suspension would bottom out
   b) very soft since the suspension would now ride on the soft dampers

9. How would your car’s suspension feel if the dampers broke?
   a) very hard since the suspension would bottom out
   b) very bouncy since the suspension would be ride on the bouncy springs

10. If a car hits a pothole, it will tend to bounce at a particular frequency (that is, cycles per second) set by the springs and dampers. How would this frequency change if the car was transported to the moon?
    a) bounce at a lower frequency
    b) unchanged
    c) bounce at a higher frequency

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He is a professor of electrical engineering at the Virginia Military Institute, Virginia. He completed his B.S. in electrical engineering from the United States Military Academy in West Point, New York. He was awarded a Bronze Star during his service in the army as a military intelligence officer during a desert storm. He was selected as Virginia's Rising Star professor at VMI. He was also selected to become an honorary member of the Class of 2009. He is a licensed professional engineer in Massachusetts and Virginia. He is also an active consulting practitioner.

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He is a professor of mechanical engineering at the Virginia Military Institute. He received his B.S.M.E. from the University of Vermont and Ph.D. from the Rensselaer Polytechnic Institute. He holds teaching positions at the University of Michigan-Dearborn and the University of Vermont. He was employed by JMAR Inc. before joining as a faculty in the Virginia Military Institute in 2004. He was involved in the research and development of X-ray lithography systems for the semiconductor industry. He has published several papers in national and international journals.

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DISCLAIMER
This chapter is an extended version of the article published by the same author(s) in the following journal.
IEEE Frontiers in Education Conference, 2009. DOI: 10.1109/FIE.2009.5350485

Peer-Review History:
This chapter was reviewed by following the Advanced Open Peer Review policy. This chapter was thoroughly checked to prevent plagiarism. As per editorial policy, a minimum of two peer-reviewers reviewed the manuscript. After review and revision of the manuscript, the Book Editor approved the manuscript for final publication. Peer review comments, comments of the editor(s), etc. are available here: https://peerreviewarchive.com/review-history/1380G