AC 2011-841: ROOM WITH A VUE

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John’s passion is in the visualization of materials concepts through demonstrations and experiential learning through hands on exercises. Materials engineering is everywhere, and he enjoys showing people how everyday objects are extraordinary examples of engineering!
Introduction

Engineering students have a tendency toward visual learning, however most engineering education is auditory or verbal in nature. Evidence for the strong visual nature of engineering student learning is seen in Figure 1. Data used to construct Figure 1 was obtained by having students voluntarily take an online index of learning styles questionnaire (hosted at North Carolina State University). The index of learning styles questionnaire covers a multitude of learning styles, for which the respondents reported, however only the visual and verbal style data.

![Figure 1](image-url)  
**Figure 1.** Collected learning style data from multiple introductory service courses in second year materials engineering undergraduate courses (time span: 2005-2010). The percentage of each class as a function of the tendency toward visual or verbal learning is plotted. The far left end of the learning style axis denotes highly visual learners, whereas the far right end denotes highly verbal learners. The middle ground is where no noticeable tendency toward visual or verbal learning is observed. Sample size, N, of the different classes is shown.
are presented (the trend of visual-verbal learning style has not seemed to change drastically over the 6 years over which the author has taught an introductory materials engineering course to many disciplines of second year students – regardless of class size or institution). Figure 1 shows that often a quarter of the students are considered to be strong visual learners (by integrating the area under the curves), and the results indicate that engineering students are rarely strong verbal learners. However, as previously mentioned much of engineering education is verbal. The disconnect between learning style and teaching style should presumably result in imminent failure in the classroom, however such disaster can be prevented. Felder and Silverman\textsuperscript{1} suggest that understanding the learning styles of the student body is fundamental to adapting teaching styles for more effective learning.

Taking the necessity to adapt teaching style as a starting point, this paper addresses how to improve upon visual learning in large introductory service courses by using a system designed to be inherently easy for engineering students to achieve efficient and effective learning. This paper will introduce a teaching approach called \textit{“Room with A VUE”}, which is a pedagogical framework developed to create an environment which aids in enhancing student learning by making concepts Accessible, Visual, Unexpected, and Engaging.

By creating a room in which the students find information accessible they cannot help but be prompted into recalling their tacit knowledge, and most importantly they are emotionally comfortable. By achieving a visual presentation of the concept the students again are comfortable and more likely to pay attention because their learning style is being activated. By showing something unexpected the students realize a gap in their knowledge and have a newfound fascination and personal motivation for solving the mystery. The preceding steps help to engage the students on an emotional, behavioral, and cognitive level, and thus induce intrinsic motivation.

This paper will discuss the pedagogy of the \textit{“Room with A VUE”} system and conclude with a case study of curriculum development aimed at creating hands-on exploration experiments in materials engineering to apply the system. This paper is not meant to be a resource of visual demonstrations – such a resource is forthcoming from the author.

The system to be discussed is rooted in the psychological motifs of behavioral, emotional, and cognitive engagement. Motivation for the work presented herein is to provide experiences for engineering students that align with their predominant visual learning style whilst also providing opportunities, across all three levels of engagement, for development of intrinsic motivation and understanding of how materials work in the surrounding world.

**Pedagogy**

Pedagogically, adapting to visual learning styles has resulted in more visual presentation of material in learning environments. Strategies range from diagrams to performing or referring to demonstrations, photos, and schematics. However, visual learning is not necessarily achieved through mere visual presentation and viewing of teaching materials. Visualization of complex concepts is an active process involving visual thinking; looking is not seeing, nor is seeing
necessarily believing, understanding, and being able to demonstrate knowledge. Upon viewing a new concept students often reflect about their own tacit knowledge and try to make a connection to the new concept, thereby creating their own knowledge. Unfortunately, as educators we often assume we don’t have control, or even awareness, of such connections in each of our students’ minds, thus it is exceedingly difficult to correct miss-steps along the way. However, by taking a proactive and creative approach, we can guide the visualization process through seeded common experiences generated in the classroom, study hall, or laboratory.

Setting the stage for learning in many courses requires that the students realize that they lack sufficient knowledge in the subject, and that they require such knowledge to be able to perform as professionals. It could be argued that masterfully performing the task of exposing the knowledge gap in students’ minds is a critical component in effective and efficient education. Figure 2 is my attempt to address the knowledge gap on the very first day of lecture in a new semester. Sticking with the predominant learning style, notice that Figure 2 is highly visual, and demonstrates that the students’ brains will change as a direct result of the knowledge they will gain, and that they will be ably suited to use their changed brains to perform tasks via use of their new hands. The cartoon form is used to make the idea easily accessible, understood, and easily presentable. Cartoons are usually humourous, and humour in this instance is invoked to assist in creating emotional comfort with the fact that the students are effectively being told that they don’t know something, which when putting oneself in the students’ position, could be a very confrontational and insulting remark.

![Figure 2](image_url)

**Figure 2.** Cartoon explaining how the second year materials course (Mat E 202) will be transformative in exposing and filling the knowledge gap in students’ minds and enabling them to perform tasks based on their new “materials” knowledge. This graphic was developed during an airplane trip during the process of reading “Made to Stick” and “Back of the Napkin”. The cartoon is drawn on the whiteboard the first day of classes to set the stage for the type of learning that is expected, and to be presented.
David Katz has remarked very poignantly about the difference between science and magic: “Magic is science without the explanations.”\(^5\) Further interpretation yields an inherent knowledge gap associated with magic; the lack of understanding drives us to figure out how the “trick” works. A paramount lesson is captured when considering Katz’s statement with regard to classroom demonstrations (his original intent): remember to focus on the explanation and to reinforce the explanation, not the magic. Use the magical aspect of a demonstration to expose the knowledge gap and create a visually appealing and unexpected atmosphere, but focus much of the attention on the learning opportunity by going over the science and engineering fundamentals giving rise to the phenomena. An important aspect of the “magic” of demonstrations is in engagement and emotional response. The magic draws our attention because we are fooled into an alternate reality of the unexpected; we become emotionally and cognitively engaged in the puzzle. Emotional responses to information make the information stickier\(^3\), i.e., emotions play a central role in knowledge creation and recall, and allow for information to be retained.

**Accessibility**

Accessibility is a critical and fundamental step in achieving unobstructed comprehension – a starting point, or lowest common denominator. Student confidence can be established by presenting information at a level that can immediately be understood. Adjacent layering of information builds on the initial accessible step, which allows for development of more involved or complicated knowledge.

Hirschhorn *et al.*\(^6\) remark that in their development of a materials science and engineering course for non-technical students that classroom demonstrations alleviate many students’ fear of science and technology. The use of common materials and equipment allows for the possibility for students to carry out the experiments themselves\(^6\). Such a sense of emotional comfort is central to the theme presented at present: accessibility to the subject matter is critical when considering student response to learning in general. When considering visual learning in particular, the more comfortable the object, equipment, material, or process, the freer the mind for watching and *seeing* the concept to be demonstrated. Reflection of the event can also then be focused on what happened, and not on identification of the parts.

**Visualization**

Visual learning is not simply “seeing is believing”. Visual learners analyze information using the process of visual thinking, which is a method to describe thinking with pictures. Visual thinkers recall memories through visual cues, or by imagining pictures that explain their thinking. The provision of pre-constructed images may or may not help visual thinkers. Providing a series of visual cues punctuated with verbal cues allows the visual learner to construct their own mental picture built on their own tacit knowledge and experience, and then incorporate the new information. Very strong images have a tendency to be memorable. An unexpected outcome couples an emotional response to the subject matter, thus having a higher probability of creeping into and crystallizing in the visual mental picture.
Unexpectedness

Curiosity can be invoked immediately by introducing an unexpected outcome or event surrounding an accessible object. Many teaching styles start with accessibility and visualization, however the unexpectedness step is critical, and a defining characteristic of the teaching techniques developed with the system. Rather than discuss this point further, a demonstration of such unexpectedness follows.

Imagine an egg-shaped container of the childhood toy Silly Putty™. What can (or have) you done with a small quantity of Silly Putty™? Perhaps you have stretched it, snapped it, or bounced it. Maybe even lifted ink off a cartoon page and distorted the image. Well, now imagine that you have access to five pounds of Silly Putty™. What do you imagine you would do with so much? Well, with some materials engineering knowledge, creativity, and application of “Room with A VUE”, you can use Silly Putty™ as a hammer to pound steel nails through wooden planks! Chances are you did not expect that possible answer, and neither do students. But how would you accomplish such a task? Very high strain rates, or lowering the temperature are the most fundamental routes for changing the mechanical response of many polymeric materials such as Silly Putty™. Many students have observed that hitting Silly Putty™ with a hammer will cause it to shatter, and many suspect that cooling a Silly Putty™ hammer will embrittle it and cause it to shatter when struck. However, Figure 3 shows direct evidence of a usable Silly Putty™ hammer developed by the author for use in the classroom to demonstrate reversible thermal transitions in polymers.

Figure 3. a)-c) Samples of wood with nails driven through them with a liquid nitrogen cooled Silly Putty™ hammer, d). Notice in d) the hammer handle has remained soft and crept down the edge of the lab bench whereas the hammer end is cold and has nucleated ice crystals. The board with the writing on it (a) and b)) is on permanent display in the author’s office to encourage all those who see it to hazard a guess. Photos © John A. Nychka, 2010.
The Silly Putty™ hammer demonstration has been developed to expose the knowledge gap in the mechanical response of polymers as a function of temperature and strain rate through extreme unexpectedness! The hammer has been “frozen” in liquid nitrogen but the handle remains soft and creeps at room temperature. The action of cooling the hammer actually tempers the putty to induce residual compressive stresses on the surface to prevent tensile cracking and damage when struck (the process is akin to the tempering of a polymeric glass).

By using the example of the Silly Putty™ hammer a totally unexpected event is powerful in creating an emotional and visual tie to the event (e.g., surprise or disbelief), and hence the mental image forming ability of the activity is enhanced. Many such activities are possible in materials engineering, and a good resource with standard fair is “Demoworks: The Fine Art of Materials Science Demonstrations.”

Engagement

Concerning the definitions of the three types of engagement Fredericks et al. write:

“The multifaceted nature of engagement is also reflected in the research literature, which defines engagement in three ways. Behavioral engagement draws on the idea of participation; it includes involvement in academic and social or extracurricular activities and is considered crucial for achieving positive academic outcomes and preventing dropping out. Emotional engagement encompasses positive and negative reactions to teachers, classmates, academics, and school and is presumed to create ties to an institution and influence willingness to do the work. Finally, cognitive engagement draws on the idea of investment; it incorporates thoughtfulness and willingness to exert the effort necessary to comprehend complex ideas and master difficult skills.”

The multifaceted nature of engagement permits many inroads to affecting student interest in subject matter, however not all types of engagement can be easily activated. For example, cognitive engagement goes beyond behavioral engagement; cognitive engagement points to a psychological quality to invest challenge, problem solving, and positive coping in the face of failure.

Pitfalls concerning engagement do exist. If disengagement, particularly behavioral disengagement occurs and is further exacerbated by particular teacher or institutional responses then student motivation for learning can be severely undermined. One never knows the key tipping points in student engagement; what statement or activity will change a student from being engaged to disengaged. Will key statement or activity for engagement or disengagement occur in the learning environment, in an extracurricular setting, or domestically? Prediction is ineffective, so preparation for activities within the learning environment to positively affect students is obviously preferred.

By following the preceding steps in the “Room with A VUE” framework, the end result leads to engagement: the students are more likely to have an intrinsic desire to understand the
reasons why the unexpected behaviour occurred, and they will have a mental picture of the concept. For example, a student quote demonstrates the strong memory forming ability of engaged visualization:

“For me, it’s like you see something and that is what sticks with you the rest of the day. When I’m writing a test, I can see that visual representation. It definitely helps.”

If all three types of engagement are accessed then the student personalizes the information, and can create their own knowledge. By achieving a strong emotional attachment to the information a persistent mental image is created, which manifests as tacit knowledge.

The Room with A VUE system has been applied by the author to create a multitude of in-class highly visual demonstrations and videos (at a minimum about 20-24 demonstrations are made over a 13 week course). Many stock videos can be found online, however there is true power and difference in a physical demonstration; much as going to the symphony is rather different than listening to the same music on a compact disc in the car. Similarly, reading about a magic trick and seeing or being part of a magic trick evoke a totally different response.

Delivery of demonstrations is also critical for learning. For maximum learning potential, the author has found that showing a demonstration multiple times is required. An informal survey of academics in various faculties confirms this approach. The first time the experiment is merely demonstrated to show the visual and unexpectedness of the phenomenon. The class is then polled for what they saw, and what they think it means. The second time the class is guided to watch for something in particular that will help them “see” the concept. Finally, the demonstration and concepts are summarized, and even written on the board for emphasis. Without going into exhaustive detail one can see that many learning styles are addressed with a demonstration. However, it is possible that active learners may be left out when demonstrations are only presented, as the presentation is teacher-centered. Another solution has been developed that aims to access many learning styles, especially the visual and active learners: hands-on student-centered demonstration kits.

Case study: “WHAT’S IN THE BOX?”

The “Room with A VUE” system has been applied in an introductory materials engineering course to large groups of students (3 sections of 100+ students each; all taking labs) with great success. The creation of a demonstration kit called “What’s in the Box?” has allowed for direct application of “Room with A VUE” in the laboratory along with the lecture hall. Students are required to purchase a kit containing common objects ranging from mechanical pencils to paper clips (Accessible) – see Figure 4. Presently the kits have 7 formalized experiments. The demonstration labs run 3 times, and for each lab session 2-3 demonstrations are performed over 1 hour of a 3 hour time slot.

Many experiments are possible with the demonstration kits, each with a visual procedure. A key element to the experiments is that each student performs the tasks; so as a result, the visual procedure often leaves out the end result – leaving some associated mystery. If the
students could read the lab manual and see everything they would be robbed of the experience of personal discovery, which is designed to elicit an emotional response. Through their lab and general training the students discover the hidden aspects of materials in everyday objects.

The students perform the hands-on demonstrations in the lab with supervision from teaching assistants and in some instances in lecture with guidance from the instructor. In-class demonstrations often have student volunteers involved. The demonstrations involve performing a task with the objects such as melting the plastic of a mechanical pencil (Visual) and stretching it out to form a long and thin filament (Unexpected). There is also a challenge to see who can make the longest filament (Engagement). The tasks are designed to demonstrate key concepts in the curriculum, reinforce the other experiments being performed in the 3 hour lab session, and especially support the concepts which are difficult to visualize. Visual learners are engaged, along with other learners: active learners have the opportunity to “do” experiments, sequential learners follow step by step instructions revealing the concept(s) piece by piece, and summary questions are provided for reflective learners. An example experiment is shown in the Appendix.

For the first time, students have remarked that the labs are fun (emotionally engaging), and the demonstrations have improved understanding of concepts as measured by targeted problems and through formative assessment.

Figure 4. The “What’s in the Box?” box and its contents: 1) Lighter, 2) Ceramic cutting tool insert, 3) Alloy 6061-T6 rod, 4) Alloy 1100 rod, 5) Egg of Silly Putty™, 6) Set of 3 postcards of various materials with descriptions on the back, 7) Mechanical pencils, 8) Bar magnet, 9) Box of 100 paper clips, 10) “What’s in the Box?” sticker. Photos © John A. Nychka 2010, 2011.
The introduction of student-centered hands-on demonstration kits is relatively new in the author’s class (less than 8 months) so a detailed assessment study has not yet been completed. However, a few targeted assessments will be discussed, along with student feedback regarding visual demonstrations.

A key to solidifying knowledge is to allow sufficient time for reflection, and to perform formative assessment shortly after delivery of the experience. Many of the teaching tools centered upon the “Room with A VUE” system have been developed to complement existing curriculum tools, especially those which involve difficult concepts. A vast majority of these activities are demonstrations – both in-class and student run demonstrations. Moreover, the new teaching tools have been developed with the requirement that no direct summative assessment be made; summative assessment has a tendency to degrade the excitement and explorative nature of the process of learning by the introduction of extrinsic motivation. Guiding questions are provided in class and with the lab demonstration kits but no work for credit is collected at the time of the events.

Targeted problems concerning the course under study have shown that activities following the “Room with A VUE” system have resulted in exceptional recall, with explanations coming directly from first hand experiences with activities for which there was no extrinsic motivation. A recent exam question probed the understanding of reversible thermal transitions and the effects of temperature and strain rate on polymer properties. In essence the problem asked students how they could fashion an axe made from Silly Putty™ and proceed to chop wood if they were trapped in Antarctica. Real log E versus temperature data was provided for a strain rate of 1Hz (see Figure 5). In one of the three lecture sections of the course an actual demonstration of a Silly Putty™ axe chopping wood was performed. The cold temperature combined with the high strain rate of hitting the axe on the wood shifts the glass transition temperature to higher temperatures resulting in glassy behavior of the putty (this is a step above the Silly Putty™ hammer discussed above!).

Students who have seen demonstrations are more likely to remember them, and recall the concept correctly than those who have not seen the demonstration. This result should be at all surprising; seeing is believing. All students were enrolled in the lab portion of the course wherein they performed experiments with their demonstration kits in addition to experiments for credit. It was found that ~30% of students (the group that had the in-class demonstration) responded by correctly explaining their first hand experience with Silly Putty™ in the lab and through direct recall of the in-class demonstration concerning the phenomenon. In the other classes (absence of demonstration) the recall of the specific in-class event were minimal (~5%; explained by students being enrolled in one section but attending another) but recall of student based discovery activities was similar in other questions on the exam. Hands-on activities, following the “Room with A VUE” system, were developed to instill a sense of discovery, and they were found to be a significant trigger for memory forming and recall.

Visual demonstrations are strong memory devices, but is the recall correct? Initial evidence points to yes, but a detailed study should be completed. Students recalling actual events
seldom misunderstand what physically happened. However, not all students have mastery of the theory, or its application. Regarding the axe demonstration and targeted problem, a twist was put in the exam question – the temperature was not low enough to permit a complete glass transition; students had to realize that the strain rate effect, in addition to cold temperature, was critical in solving the problem. The students rose to the challenge, and by including the graph in Figure 5 as a visual aid many students correctly understood both factors were part of the solution. Visual demonstrations have the potential to improve problem solving ability along with memory recall. 

Many targeted homework assignment problems have also been based on demonstrations (those in class or in the lab) and similar results regarding memory recall and problem solving ability have been found. A more detailed study should be performed, and a formal student survey focused on demonstrations is being developed so that statistics can be collected. 

Feedback from student comments on course evaluation questionnaires is also very telling concerning the effectiveness of classroom demonstrations that follow the “Room with A VUE” system. In multiple classes of >100, all students who wrote comments (>60%) commented that their favorite aspect of the course was the in-class demonstrations and experiments, and many of those (30%) further explained that the demonstrations were so good because they helped them to visualize difficult concepts. A small group of course alumni interviewed two years after taking the course have had similar comments regarding the effectiveness of the demonstrations, and some have even tried to perform the demonstrations for family members over holiday breaks! 

![Figure 5. Modulus versus temperature plot for a silly putty disc (9.00 mm diameter x 4.20mm thick; punch seen in top right image) tested in a dynamic mechanical analyzer (DMA: Perkin Elmer DMA 8000; bottom right image). The silly putty was clamped and tested in compression as seen in the middle image at right. Credits: data collected by Dr. Anastasia Elias (March 2010), photos © John A. Nychka 2009.](image-url)
Students recall the in-class demonstrations, and the more unexpected the outcome, the more memorable the experience. Further study into the potential for enhanced problem solving ability as a result of visual demonstrations will also be performed.

Conclusions

An effective pedagogical teaching system, “Room with A VUE”, has been developed by considering basic psychological aspects of teaching and learning. Creating demonstrations and hands-on experiments which were accessible, visual, unexpected, and engaging resulted in high levels of student motivation and enthusiasm, along with increased performance and recall on targeted questions on exams. Creation of an environment which demonstrated the mystery and lack of knowledge concerning the subject of materials engineering allowed for effective knowledge translation from teacher to student – students understood that they had a need to learn and were responsible for their learning. Comprehension commencing with common experience was expanded through the use of visualization, which played to the strong tendency of visual thinking in the engineering classroom. Emotionally involving the students in the subject matter was an effective method of engagement on multiple levels. The increased levels of engagement, enthusiasm, and commitment to learning resulted in increased performance and enjoyment in the course. Time will tell how strongly the knowledge has been incorporated into the minds of the students, but one outcome is certain – the students will never again look at Silly Putty™ in the same way.

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Bibliography


Lab Seminar #4

Experiments to be performed today (lab manual):
   1. Eutectic Microstructure
   2. Heat Treatment of Steels

Demos to be performed today (this worksheet):
   1. You-Teck-Tick; You-Teck-Toyed
   2. Spring to it!

Young-Tick; Young-Toyed
(Eutectic; Eutectoid)

This experiment will help you observe and learn about:
   A. The appearance of the eutectic and eutectoid microstructures.

Procedure

1. Begin by putting on your safety glasses!
   ☢️ Small particles of graphite dust may get in your eyes, on your hands or clothing!!! Graphite is not harmful when contact with skin, but you should not inhale graphite dust!!! Wash your hands with soap and water after doing this experiment.

   You will need a mortar and pestle for this experiment. Your TA will provide it for shared use on the table.

2. If you saved the graphite from other pencils pull it out now. If not, take another mechanical pencil and extract the graphite.
3. Begin by breaking 4 pieces of graphite into smaller pieces (about 3 mm long) and placing them in the mortar and pestle. **SLOWLY** grind the graphite into a fine powder by making an orbital motion with the pestle against the mortar.

4. Take two pinches of silly putty. Set one pinch aside and stick the other to your index finger. Press the silly putty into the graphite powder in the mortar. Be careful not to spill any graphite powder.

5. Above the mortar, carefully fold the silly putty over on itself and then fold the ends over as well (like you are making graphite filled silly putty burrito!). Do this over and over again until the silly putty is a solid colour of dark grey. You may get graphite powder on your hands, but it will wash off with soap and water and is not harmful.
6. Roll out your pinches of silly putty into rods. Place them together along their length and squish them together to make a flat bar.

7. Tear the bar into 4 pieces and stack them atop each other so that you make a laminate of alternating colours of silly putty. Repeat this tearing and stacking procedure 2 or 3 times until you have a stack similar to that shown below at right.

8. Tear the stack one last time and rotate the top piece 90° before placing it on the bottom piece. Roll the stack into a rod again, and then squish its ends together between your thumb and index finger.
9. Flatten the putty on the table with the palm of your hand then flip it over to observe. You have made a model of a polycrystalline eutectic or eutectoid microstructure!

The putty model you made represents a characteristic eutectic or eutectoid structure (often called Pearlite – which is a structure of alternating lamellae of two phases within each grain). In real engineering materials Pearlite forms in a very different way than the way you made the model, for a variety of different materials based on their phase diagrams. Nonetheless, there are some similarities in structure that your model can help you visualize in real microstructures:

- You will see (or have seen) a similar (Pearlitic) structure in the microscope, yet the structures in the microscope are formed due to phase transformations inside grains during relatively slow cooling from high temperature – not from physically laminated and deforming different phases.
- There is a variation in how the plates appear based on how the lamellae are sectioned in metallographic sample preparation. Spacing, direction, and orientation of lamellae can vary from grain to grain.
- Pearlitic grains contain alternating lamellae made from different solid phases of material (each phase has a different crystal structure and composition). The silly putty is different based on its colour, and also presence, or absence, of graphite.

**Note:** if you want to protect the rest of your silly putty from becoming sullied by the graphitic putty just press each of the different colours into separate halves of the egg shell container to keep them from touching. Once the colours mix it is permanent!

**Questions**

1. Many materials of eutectic (or eutectoid) composition have a Pearlitic structure of two alternating phases. Everything else being equal, how will the microstructure vary if the composition is not exactly at the eutectic or eutectoid composition? (i.e., hyper or hypoeutectic or hyper or hypoeutectoid)?

2. This experiment can help you visualize and remember certain steel microstructures: in the microscope the dark lamellar phase in Pearlite is Fe₃C (cementite: a hard and brittle intermetallic phase with a lot of carbon); the white phase in Pearlite is α-ferrite (a soft and ductile phase of iron with almost no carbon). Imagine the tan silly putty is iron (α-ferrite); the silly putty you added the graphite (carbon) to is cementite (Fe₃C). Refer to the phase diagram on the last page to see the phases.

3. How do dislocations move through the structure of Pearlite? Would Pearlite be harder or softer than i) α-Fe (α-ferrite), ii) Fe₃C (cementite)? Why?