Catching Students' Interest and Curiosity through Demonstration

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Abstract—**Our experience in integrating demonstrations into Physics lectures, during a first-year thermodynamics course, has yielded exceedingly positive feedback from students. This approach has dual benefits: it boosts campus attendance and creates a vibrant classroom environment wherein both educators and students collaboratively explore new knowledge. The main challenge with this approach lies in how to effectively integrate demonstrations into lectures in order to achieve optimal teaching and learning outcomes. This necessitates discussions on how to maintain students' active engagement in class while maximizing the benefits of the demonstrations for long-term learning. In this paper, we will categorize demonstrations based on different perspectives and analyze their applicable conditions.**

Index Terms—**Interactive demonstration, active learning**

I. INTRODUCTION

EQUATIONS and formulas prevalent in natural sciences, such as Physics, often present abstract challenges that hinder students' understanding. The theories and concepts introduced during courses can easily fade from memory as abstract things without any real-world connection or relevance. This is particularly relevant for bachelor's students, who might have limited opportunities for hands-on research to invigorate and deepen their understanding. So, the challenge for us as teachers is how can we foster students' intuitive comprehension of the world and aid them in understanding and retaining complex concepts during their studies?

One solution is to incorporate demonstrations during lectures to illustrate how abstract concepts find practical applications. However, passive demonstrations are often misunderstood by students and, as a result, may not significantly enhance student learning (Zimrot and Ashkenazi, 2007). In contrast, the integration of demonstrations with active learning techniques, also known as interactive lecture demonstrations (ILD), has been shown to be an effective method in capturing students' interest and fostering deeper learning. This approach encourages students to actively engage with and apply the information, rather than passively receiving it (Mazzolini et al., 2011). ILD can prove particularly impactful in fields where practical application and problem-solving skills are paramount, as they serve to bridge the divide between theoretical knowledge and real-world applications. ILDs have been demonstrated through Physics education research to enhance student learning of complex Physics concepts (Sokoloff and Thornton, 2006).

Over the past few years, we have been engaged in the revitalization of the thermodynamics course for first-year science students. Our strategy to improve learning has been to attempt to integrate various active learning activities into the established traditional teaching program. We have experimented with ILD in both large classes, consisting of approximately 20-30 students, and in smaller groups of 4-5 students per group. As ILD gradually takes precedence over traditional-style lectures, students are afforded greater opportunities to engage with demonstrations, resulting in increased participation and activity.

II. METHODOLOGY - USING ACTIVE LEARNING TECHNIQUES FOR INTERACTIVE DEMONSTRATION

A. Active learning

Active learning represents a pedagogical approach that encourages students to actively engage in the learning process by thinking, discussing, investigating, and creating. This stands in contrast to traditional passive learning styles, where knowledge is primarily transmitted from teacher to student, often relying on conventional teaching methods. In passive learning, our brain often asks, 'Do I understand it?' instead of inquiring 'Why is it?' and 'How can I understand it?' as encouraged in active learning.

To understand why active learning is so effective, it's important to know that our brains have a decision-making process when it comes to memory retention. When assimilating new information, the brain instinctively seeks to integrate it with existing knowledge, forming a cohesive framework. In instances where foundational knowledge is absent, the brain encounters difficulty in assimilating novel information, potentially leading to its dismissal. In other words, your brain needs to build foundation neutron connections for new information to attach to, which is both why active learning is more mental work but also essential for learning.

Here are some examples of active learning techniques that have been applied in our course:

1. **Group Discussions**: Encouraging students to discuss topics, share their perspectives, and exchange ideas fosters a collaborative learning environment.
2. **Think-Pair-Share**: Students first think individually about a question or topic, then pair up with a classmate to discuss their thoughts, and finally share their ideas with the whole class.

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3. **Case-Based Learning**: Presenting real-world scenarios or case studies for students to analyze, problem-solve, and apply their knowledge in practical situations.
4. **Jigsaw Technique**: Breaking down a complex topic into smaller pieces, assigning each piece to different groups of students, and then having them collaborate to understand and present the complete concept.
5. **Interactive Lectures**: Incorporating polls, quizzes, discussions, and activities during lectures to keep students engaged and actively participating.
6. **Problem-Solving Exercises**: Providing structured problems or small exercises that challenge students to apply their knowledge to find solutions.
7. **Inquiry-Based Learning:** Encouraging students to ask questions, conduct research, and investigate either topics independently or in groups.

B. Integration of active learning with interactive demonstration

Demonstrations can capture students’ interest, but on their own, they may not lead to deep learning. To achieve deeper understanding, it's crucial to combine demonstrations with active learning techniques that engage the students. Research has shown that students who only observe demonstrations without engaging in prediction and discussion tend to experience a decline in their ability to recall the outcomes (Zimrot and Ashkenazi, 2007). In our lectures, we introduce several key methods that integrate active learning with demonstrations:

1. **Prediction Model:** This model, often referred to as POE (predict–observe–explain) (Den Otter et al., 2021) or PODS (predict–observe–discuss–synthesize) (Tanahoung et al., 2009; Mazzolini et al., 2011), involves students predicting the outcomes of the demonstration and discussing them in small groups before actually witnessing the demonstration during the experiment. They then work with the results and reflect on the outcomes, explaining why they initially held their beliefs and in what ways the demonstration confirmed or contradicted those beliefs. This process leads to the discovery of knowledge. The prediction method is particularly effective at the start of a lecture, as it piques students' curiosity about new knowledge.

2. **Validation Model**: The validation model operates in the opposite manner and is often employed towards the end of the lecture. It serves to reinforce and consolidate the knowledge that was introduced and explained earlier. It is particularly useful for qualitatively demonstrating abstract concepts. The validation model is also very useful for reviewing knowledge in cases where demonstrations require a significant amount of background knowledge to be able to explain the phenomenon. In this model, we first introduce new knowledge, followed by an explanation, and then proceed with a demonstration to substantiate its validity.

1. **Problem-based learning (PBL) model**: This model represents a more advanced level of learning, assuming that students are already familiar with the equipment used in the demonstrations. In this approach, we present complex problems alongside the necessary equipment. Students collaborate within their groups to strategize and execute the experiment. Following this, they are tasked with not only explaining the results but also assessing any uncertainties that may arise. This approach encourages a heightened degree of students’ independence, challenging them to apply critical thinking and problem-solving skills in order to reach a solution to a problem, which strengthens their learning and understanding.

In the prediction and validation methods, demonstrations can be conducted by teachers with students' involvement, or by small groups of students with teacher support. In contrast, PBL is primarily student-driven. Depending on factors such as available time, equipment, and students’ knowledge and experience, teachers can judiciously utilize these methods in various situations to improve learning.

III. RESULTS AND DISCUSSION

Our course comprises four chapters: Temperature and Heat, Thermal Properties of Matter, The First Law of Thermodynamics, and The Second Law of Thermodynamics. We have incorporated a total of fifteen demonstrations to the lectures, which have been categorized into Prediction, Validation and PBL models, as illustrated in Fig. 1a. In Fig. 1b, we present visual representations of the average time required for each demonstration, the level of student independence, and the engagement levels for each model. Student engagement is assessed based on their involvement in problem-solving activities. A list of demonstrations is provided in the appendix. It's crucial to highlight that the number of students who successfully completed the course and their final grades were not considered in this study. This aspect may be explored in future research to provide a more thorough assessment of the impact of ILD.

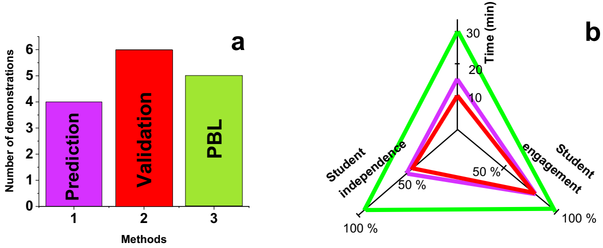

Figure 1: (a) Number of demonstration applied in the course (b) Correlation between Prediction (1), Validation (2) and Problem-based learning (PLB) (3) models with students’ independence, their engagements and spending time.

The demonstrations were designed to fit within the allotted time frame in the course. In total, we had 720 minutes for the lectures, with interactive demonstrations (including explanation) comprising approximately 37.5% of the total time, as shown in Fig. 2a. In other words, the acquisition of new knowledge via ILD accounted for around one third of the total time.

Based on 50 feedback responses at the end of the course, 100% of students highly appreciate the demonstrations and find them helpful. This feedback reflects the students’ keen interest and curiosity. In Fig. 2b, we present how students comparatively assess the significance and appeal of implementing ILD in their learning journey. 86% of the assessments range from very good to excellent (4-5 stars), while 14% fall below very good (2-3 stars). The students who rated ILD below very good explained in their comments that either they did not attend all the lectures or they believe more time should be allocated to theory and problem-solving exercises during the lectures, which are directly connected to the exams. It is evident that students have varying approaches to acquiring new knowledge, as well as different expectations. As teachers, there is still room for us to optimize our teaching methods to foster deep learning and nurture students' skills, interests, and creativity.

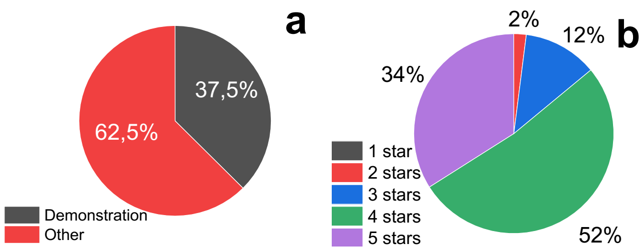

Figure 2: a) The percentage of time used for interactive demonstration b) The five-star rating scale of lectures. Percentage of assessment from 1 → 5 stars correspond to poor, marginal, good, very good, excellent/outstanding

IV. CONCLUSION AND OUTLOOK

Looking ahead, there are several avenues for further research and development in this area. Firstly, a more extensive evaluation of the long-term impact of this pedagogical approach on students' retention of thermodynamics concepts would provide valuable insights into its sustained effectiveness. Additionally, exploring the applicability of this model in other fields of natural sciences and beyond could yield valuable implications for broader educational contexts.

Furthermore, investigating the scalability of these techniques to larger class sizes and diverse student populations would help ensure that this approach remains inclusive and accessible. Additionally, the integration of technology and virtual simulations could further enhance the effectiveness of demonstrations and active learning in both in-person and online learning environments.

In conclusion, our research suggests that the integration of demonstrations with active learning techniques represents a promising pedagogical approach with the potential to revolutionize the teaching of complex scientific concepts. As we continue to refine and expand these methods, we anticipate a positive impact on the learning experiences and outcomes of students in diverse educational settings.

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REFERENCES

Mazzolini, A. *et al.* (2011) “The use of interactive lecture demonstrations to improve students ’ understanding of operational amplifiers in a tertiary introductory electronics course,” *Latin American Journal of Physics Education*, 5(1), pp. 147–153.

Den Otter, M. J. *et al.* (2021) “Two design principles for the design of demonstrations to enhance structure–property reasoning,” *Education Sciences*, 11(9). doi: 10.3390/educsci11090504.

Sokoloff, D. R. and Thornton, R. K. (2006) *Interactive Lecture Demonstrations: Active Learning in Introductory Physics*. Wiley.

Tanahoung, C. *et al.* (2009) “The effect of Interactive Lecture Demonstrations on students’ understanding of heat and temperature: A study from Thailand,” *Research in Science and Technological Education*, 27(1), pp. 61–74. doi: 10.1080/02635140802658909.

Zimrot, R. and Ashkenazi, G. (2007) “Interactive lecture demonstrations: A tool for exploring and enhancing conceptual change,” *Chemistry Education Research and Practice*, 8(2), pp. 197–211. doi: 10.1039/B6RP90030E.

APPENDIX

List of demonstrations used in the course and their corresponded ILD models

Prediction model:

- Correlation between Volume, Pressure and Temperature: Volume of balloon changes when sunk in liquid nitrogen, boiling temperatures of water at different pressure
- Temperature is used to measure thermodynamic: Observing motion of colors in two different temperature cups of water and measuring their temperatures
- Thermal expansion of solid plate and hollow plate
- Thermal conductivity of material (2 plates with different materials)

Validation model:

- Determining Absolute zero
- Thermal radiation of different surface properties
- Thermal radiation speed is very fast
- Temperature does not change during phase transfer
- Burning flame on hand
- Applications of isotherm, isobar and isochoric process in real life

Problem-based learning (PBL) model

- Determine room humidity
- Determine work performance of a piston when change the air temperature in the cylinder.
- Entropy
- Heat engine,
- Refrigerator