Innovative Hands-on Teaching Tools Inspiring Upcoming Petroleum Engineers and K-12 Students

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Abstract: Petroleum engineering is a challenging discipline. Hydrocarbons were generated millions of years ago and located miles away under the ground. Teaching petroleum engineering to college students requires the pursuit of innovative educational tools. Teaching high school students and non-technical audience necessitates more creative methods. These tools include 3D-printed oil and gas field equipment and hands-on experiments that tell the story of oil and gas from generation to consumption. Also, this contains utilizing a state-of-the-art drilling simulator to re-drill vertical or horizontal oil and gas wells especially in Wyoming fields. This simulator can also be coupled with a virtual reality snapshot for an actual drilling rig located in the 3D visualization center (CAVE).

Students' education improved significantly when these tools were utilized starting in August 2017 at the University of Wyoming. The evaluation showed that more college students were able to develop a deeper understanding and to advance their knowledge. Furthermore, the outcome of these tools was outstanding in summer 2018 during the "Wyoming Energy for You" course to high school students from around Wyoming. One student described his experience as "My learning experience has definitely become better, and I have already learned more than I expected. I learned how to use a simulator and the basics that go along with that. As well as learning in depth things surround the career of petroleum engineering, by having many useful hands-on activities". Also, in one of the elementary school visits, a student in fourth grade described his experience as an epic. In conclusion, utilizing these innovative hands-on teaching tools proved to inspire the upcoming petroleum engineers and K-12 students. These results confirm that petroleum engineering instructors should implement more of these tools in their challenging courses and K-12 outreach events.

INTRODUCTION

Petroleum engineering discipline is unique. It embraces knowledge from chemical, mechanical, civil, and electrical engineering. Imagination and creativity are the dominant traits that set petroleum engineers apart from other engineers. Usually, rocket science is the reference for sophisticated subjects. However, one can argue that petroleum engineering is as complicated as, if not more than, rocket science. Petroleum engineers deal with unknowns that happened millions of years ago and are located miles away into the mysteries of earth rocks [1]. In addition, petroleum engineers do not have the luxury of seeing, smelling, touching, and in general, developing an intuitive feel for the deep oil and gas reservoirs that they are dealing with [2].

In 2010, the Society of Petroleum Engineers surveyed the responsibility to increase public awareness about energy. Responses showed that 97% believe that the industry bears this responsibility, 89% feel personally responsible, and 82% claim that the main channel to reach the public is academia. This study also argued that energy literate society appreciates the inevitable role of energy in its well-being and quality of life. Such a community is capable of directing its elected representatives to articulate sustainable energy policies [3]. However, the level of energy's public knowledge is still insufficient. This is probably because some university courses overstate concerns about fossil fuels to merely stress the benefits of renewable energy resources [4].

It is essential to develop a fact-based energy education for college and K-12 students. The Society of Petroleum Engineers (SPE) continues to energize its members to be their industry's champions. SPE recommends visiting local schools, civic organizations, and other groups with facts about the benefits of having an economical and reliable source of energy [5].

Energy Education Challenges

Technology marvels are breaking down the barriers of time and space and redefining the concepts of classroom education. Besides, the communication revolution and globalization, petroleum engineering education needs to continue to evolve to meet the future industry and education challenges [6]. Today, in the internet era, students process information fundamentally different than the previous generation, yet academia continues to employ traditional teaching methods. This new generation of students is characterized as "digital natives". These students are accustomed to hunting information quickly and from multiple sources and they are comfortable with parallel processing and multi-tasking. This generation also learns through networking with others and prefers pictures and videos more than sounds and text [7]. Hence, there are some attempts in petroleum engineering programs to adopt active learning and team-based education.

In 2010, Texas A&M University established a new concept called "ad-hoc hands-on teaching," in which graduate and undergraduate students are involved in designing and developing experimental apparatus. The results show that implementing hands-on teaching enhanced understanding of engineering processes and machinery equipment amongst petroleum engineering students. It also helped them advancing their team-work and communication skills [8]. Moreover, in 2010, Texas A&M University in Qatar utilized 3D immersive visualization CAVE for reservoir rocks' pore spaces and enhanced oil recovery process simulation. This approach offered students a better understanding, improved the learning environment, and accelerated the learning process [2].

Learning Styles and Retention Rates

Figure 1 shows the Felder and Silverman's Index of Learning Style (ILS). There are four dimensions of learning styles. Each of the four dimensions has two different preferences. These dimensions and preferences are (1) active/reflective, (2) sensing/intuitive, (3) visual/verbal, and (4) sequential/global [9]. The National Training Laboratories created the learning retention time pyramid also shown in Figure 1. The pyramid illustrates the percentage of learner retention rate associated with various teaching approaches. For example, the minimum retention rate is for passive/traditional teaching methods. Students retention after lectures, for example, is 5%, this can improve up to 30% by adding visual demonstrations. However, maximum retention occurs in active learning that involves student engagement. For example, group discussion improves the retention rate to 50%. This can improve up to 75% with hands-on, and retention rate could reach 90% when students teach others in team-based education [10]. The problem is that students can be active learners sometimes but reflective in other situations. It is critical to use multiple teaching pedagogies to benefit students with different learning styles and improve their retention rate.

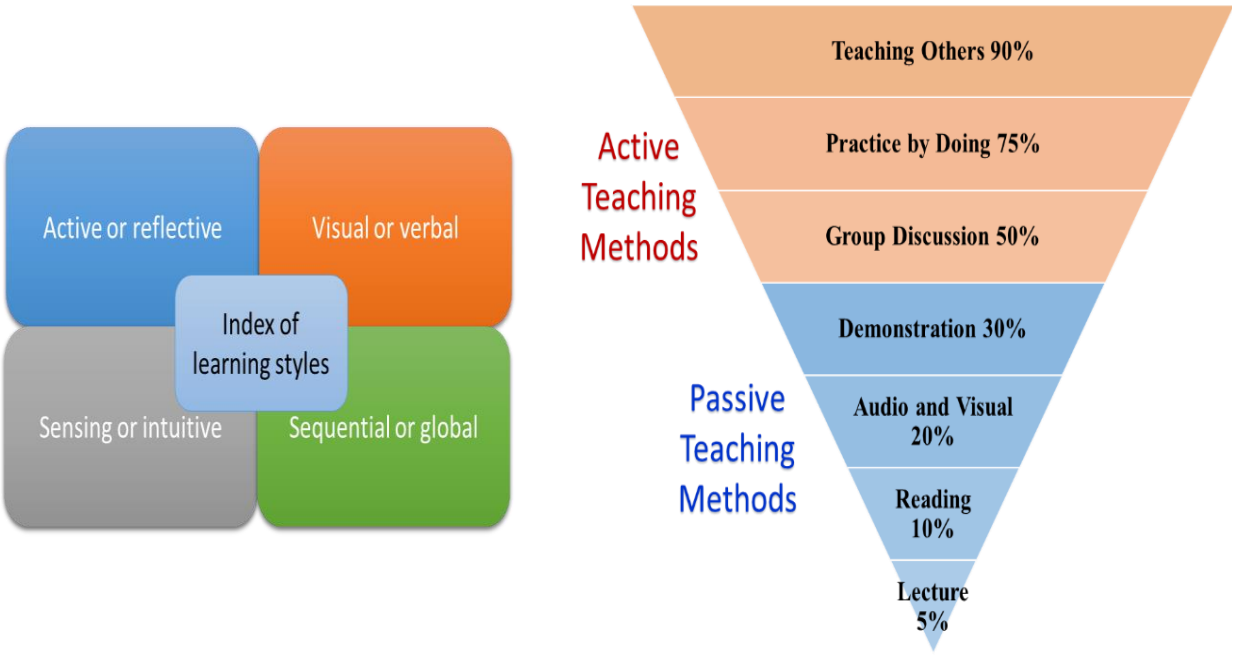

Figure 1: Index of learning styles (left) [9] and learning retention rates (right) [10]

METHODOLOGY AND PEDAGOGY

Felder defines active learning as getting students to work in small groups on brief course-related activities [11]. Benjamin Franklin once said “Tell me, I forget. Teach me, and I may remember. Involve me, and I learn.” The objective of this study is to demonstrate how active learning (hands-on) and team-based pedagogy targets the new generation of the upcoming petroleum engineers and K-12 students with diverse learning preferences.

For petroleum engineering curricula, the innovate teaching tools shown in Figure 2 include a combination of 3D-printed oil and gas field equipment, hands-on experiments/demonstrations, full-sized drilling simulator, and virtual reality snapshot located in the 3D visualization center (CAVE). Throughout these petroleum engineering courses, team-based projects to design a model that mimics specific field equipment or operation were assigned. The goals were to develop visual aids to enhance the learning process, improve critical-thinking skills, develop problem-solving skills, and polish communication and teamworking skills.

Figure 2: (a) 3D-printed drill bits, (b) hand-on demonstration, (c) drilling simulator, and (d) 3D visualization CAVE

Some of these innovative teaching tools were also used for the 2018 Summer High School energy education course. This fact-based, non-technical course was entitled “Wyoming Energy 4 You”. Students in this course were seeking conceptual understanding of the oil and gas industry in Wyoming especially issues of current importance such as hydraulic fracturing (fracking). In this course, active learning, project-based pedagogy was utilized as shown in Figure 3. This included lectures, reading and reflection, knowledge mining, hands-on activities, and competitions via Kahoot. This also included daily written feedback, industry professionals guest speakers, tours to the geological museum, visiting the UW High-Bay research facility, and working in the petroleum engineering reservoir and drilling laboratories.

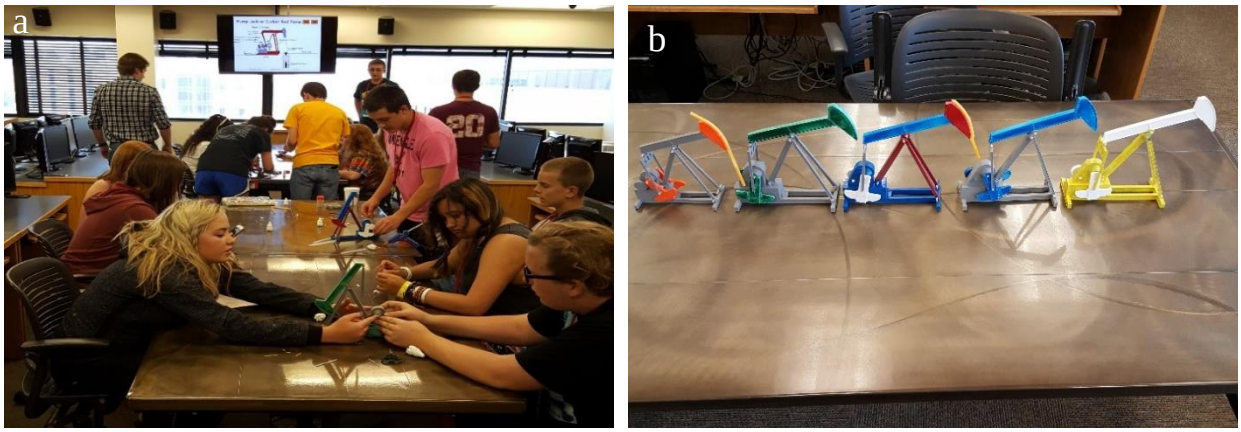

Figure 3: (a) High school students working on their team project (b) the teams' 3D-printed final pumpjack production pump

RESULTS AND DISCUSSION

Results of implementing these teaching tools reveal that students' education had significantly improved. The 2018 student evaluation showed that more college students were able to develop a deeper understanding and to advance their knowledge. This section summarized the results for (a) petroleum engineering curricula (b) 2018 summer high school course.

Part A: Petroleum Engineering Curricula Results

Figure 4 reveals the course and instructor evaluation for three petroleum engineering courses that utilized this active learning pedagogy in 2018. These courses are PETE 3725 Wellbore Operations, PETE 3255 Basic Drilling Engineering, and PETE 4990 Well Control. Results demonstrate the effectiveness of using these innovative hands-on teaching tools that benefited the current generations of students and matched their learning styles. The evaluation for the well control course was 100% in all categories. This technical elective course was designed, so the full-size simulator was used for teams' practice for at least two hours after every one-hour lecture.

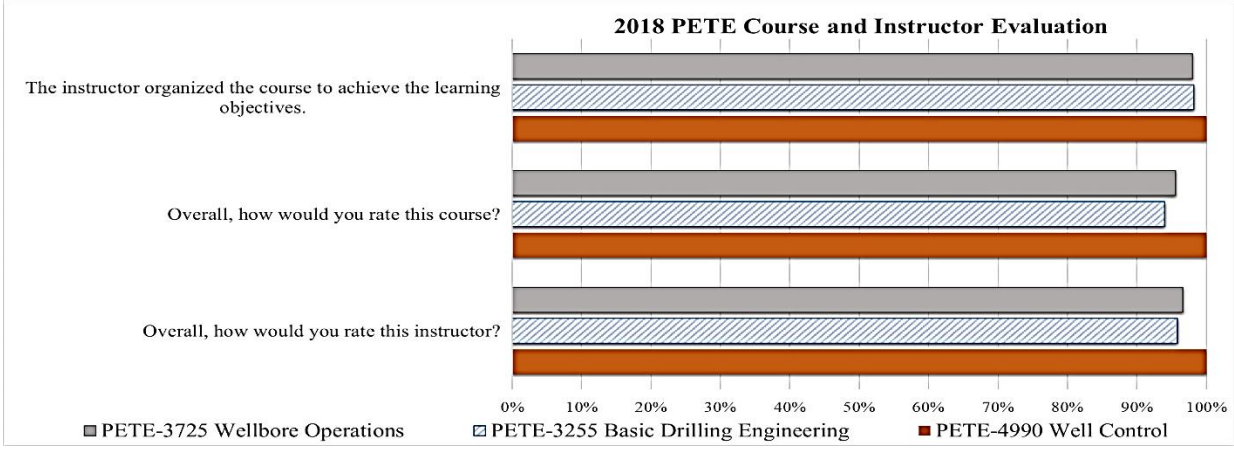

Figure 4: 2018 Petroleum engineering course and instructor evaluation

This section summarizes eight petroleum engineering students' responses to these educational tools. According to Eric Jasper "Having outside of class tools to learn really makes the course enjoyable and allows you to absorb the knowledge that is provided. Being able to apply our lectures to the "real world" practice makes you value being able to practice the lectures. Another amazing part of our class was the utilization of 3D printing. Even with these two great parts of the class, the best part the instructor did for us was his in-class demonstrations. I am very thankful the way the instructor went about teaching this course and will forever remember this beyond college."

According to Mike Gardner "Using 3D printed tools has been a valuable learning tool during my engineering degree. Using the drilling simulator has also been a valuable learning tool that gives a person a sense of what it is like to be on a rig. For myself as someone that has worked on drilling rigs, it has also been a valuable learning tool. While using the drilling simulator, you can pull up downhole graphics of what is happening. This has been a great learning tool as it brought a visualization to things that I have been doing for years. This visualization has made doing calculations for downhole problems much easier."

According to Madalyn McGuire "One of the most beneficial projects that I completed in this course was focused on the importance of hole cleaning while drilling. My team used three feet of clear tubing; then we filled the tubing with water, dish soap, and multicolored glitter. This demonstrates the way drilled cuttings would lay if not cleaned properly in vertical and horizontal wells. At certain angles, the glitter "cuttings" built up much more than others. Although this was a very simple demonstration, it was extremely beneficial for students to visually understand this concept."

According to Jared Kennedy "Incorporating hands-on learning complements the knowledge that is given in the classroom. The concept of an oil well or the reservoir is difficult to comprehend mainly because of the fact that we cannot see what is happening. Utilizing the 3D cave is one way that students can take that impossible concept to grasp and apply it in a physical medium. With the technology of 3D printing, this massive piece of steel can be modeled into a small piece of plastic that can be demonstrated in class. With the teaching tools that are incorporated in class, the transition from the class to the field is a smooth transition that places students above their peers."

According to Nickolas Brown "I think the best thing the instructor has used was the Drilling simulator with experiments to go with it, they were the best experience. It took the concepts from the classroom and applied them to the drilling simulator. This made it easier for me to understand the concepts that the instructor was trying to convey in the classroom."

According to Dean McClure "I worked in the oil and gas industry for 17 years as a lease operator and roustabout. I had the opportunity to work for first hand with much of the equipment, materials, and tools used in the production of oil and gas. During my classes, the instructor has taken advantage of actual field equipment and tools to give the students a better grasp of how things work and are used in an industry setting. In addition, the instructor has taken advantage of 3D printers to create lightweight models used for demonstration purposes. I have also had the opportunity to intern on the drilling simulator that duplicated much of the equipment that a student might expect to see on a drilling rig. Since my internship, I have also given the instructor assistance in the K-12 outreach. I will be graduating this May and returning to the industry which I love, but I will always be grateful for my experiences at the University of Wyoming."

According to Chelby Rush "As a visual learner, the integration of 3D printing into the classroom drastically improved my understanding of drilling operation. Many students will never get the opportunity to visit a drilling rig or even see drilling components in person. The addition of 3D printing has given me the chance to see life-size drilling components such as rotary and compact bits. It gave me the ability to connect what I was reading and seeing in the drilling simulator to what I will see out in the field after graduation. The impact 3D printing has had on my learning was so great, that my senior design team and I have chosen to build a 1:10 scale drilling rig model for our capstone senior design project. I truly believe this is only the beginning of 3D printings impact on the classroom. I think 3D printing is the future of teaching, especially for students that are visual learners."

According to Jessica Koivupalo "Using 3D tools and experiments in the classroom is a great way to explain complex ideas by breaking them down into illustrations that are simple and easy to understand. Tools such as the drilling simulator and the 3D cave allow students to get hands-on experience. As an intern at the drilling simulator, I have learned numerous techniques regarding drilling procedures and well control operations. This has also provided me with the opportunity to share my experiences, knowledge, and passion for the industry with youth from all over Wyoming. This not only allows my communication skills to grow but also motivates kids to begin thinking about their future endeavors and possible educational routes. Overall, I strongly believe that these tools and visual aids contribute directly to the success of current and upcoming engineering students."

Part B: 2018 Summer High School "Wyoming Energy 4 You" Course Results

This section summarizes the high school students' feedback after completing the "Wyoming Energy 4 You" course. Figure 5 shows the students' responses to four questions. These questions are: (a) how do you rate your overall experience? (b) would you recommend this course to other high school students? (c) how would you rate the course content? (d) how would you rate the course activates? Results show that the vast majority of student were very satisfied with their experience, 87% of students would "definitely" recommend this course to others, and 87% of students believed that the course content was excellent. In addition, 80% of the students indicated that the hands-on, project-based, active learning pedagogy was excellent. Furthermore, Table 1 and Table 2 summarize the students' written response to (a) how would you describe your experience, and (b) how would you describe the course activities.

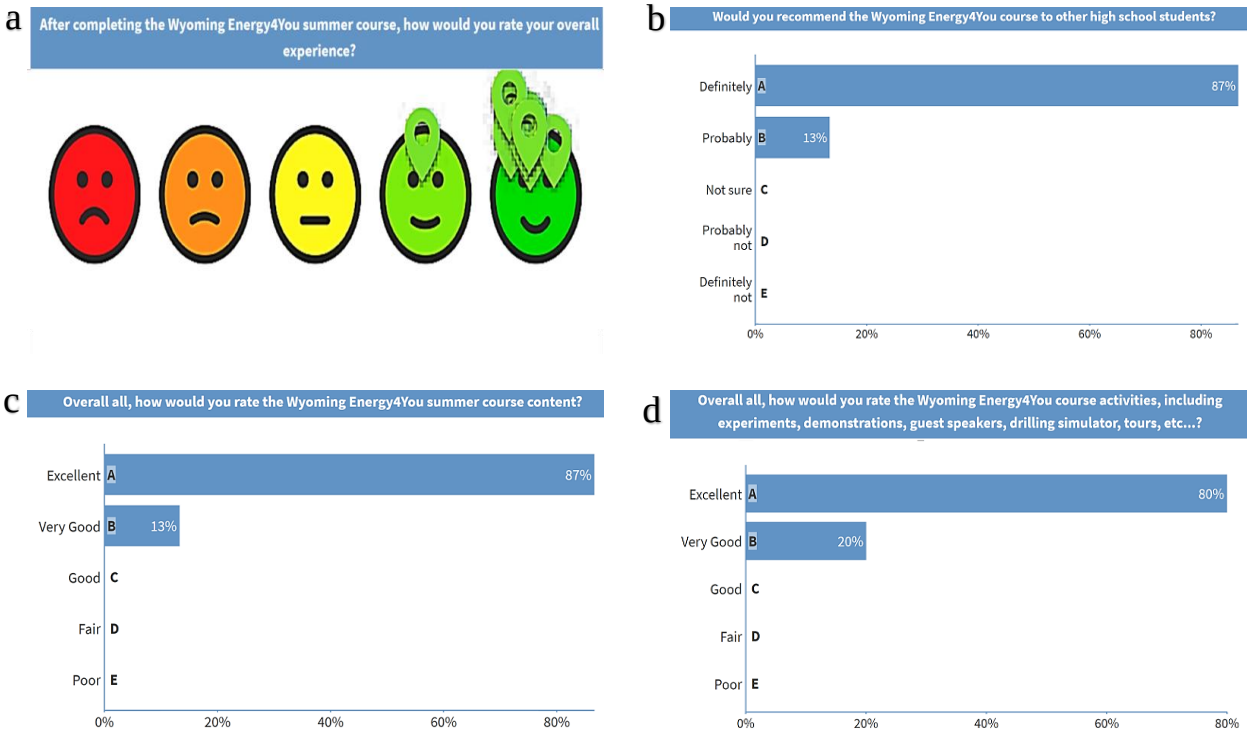

Figure 5: High school students' response to four questions after completing the "Wyoming Energy 4 You" course

Table 1: Student responses to "How would you describe your experience in Wyoming Energy 4 You summer course?"

"I would describe it as a very interactive course and very hands-on. I really enjoyed the guest speakers as there was a lot of them who were very clear in their presentations."
"My experience has been absolutely amazing. I have learned so much and had so much fun."
"I learned so much and had a blast doing everything! This instructor is a wonderful teacher. All the tours and experiments we were able to do were so fun."
"I had many hands-on activities that led me to learn about petroleum engineering and everything surrounding that field."
"It was a once in a lifetime experience."
"This is the best class that I have been in ever. This instructor is an amazing teacher and I had a lot of fun, everything was organized, and it was really great."
"Fun, interactive, hands-on activities, with a passionate teacher who is willing to do the little things to make the big things matter."

Table 2: Student responses to "How would you describe the course activities, including experiments, demonstrations, drilling simulator, tours, guest speakers, textbook reading, reflections, Kahoot questions, etc. and which one you liked most?"

"I would describe all of it as very, very good. My favorite would have to have been going to the simulator multiple times."
"The activities were so much fun! We learned the most through the field trips. The geologic museum was my favorite."
"I really liked going to High-Bay research facility; it was very fun to see how they use everything. I also enjoyed going to the drilling simulator and seeing how it worked."
"The drilling simulator was super fun. I really enjoyed all the experiments in class we did. Also, the tour of High-Bay was extremely fascinating. The debate about fracking was also very fun."
"The activities were very hands-on and let us see exactly how drilling works, through many different examples. I really enjoyed the experiments, demonstrations, and the drilling simulator the most."
"The activities we did were something I will probably never get to experience again in my lifetime. "
"I would describe this class as very interactive; there are many hands-on activities which are good for kinetic learners. I like the drilling simulators and the experiments the most, just because of my personal learning style."
"The experiments, demonstrations, drilling simulator, tours, guest speakers, textbook reading, reflections, Kahoot questions, the list goes on and on I had a whole lot of fun, and the courses were amazing, and I want to do it over again."

CONCLUSIONS

This study presents the hands-on, project-based, active learning pedagogy used in teaching the new generation of petroleum engineering and K-12 students. These innovate educational tools include a combination of 3D-printed field equipment, hands-on experiments and demonstrations, full-size drilling simulator, and a virtual reality snapshot. The student feedback showed that more college students were able to develop a deeper understanding and to advance their petroleum engineering knowledge. Furthermore, the outcome of these tools was outstanding in summer 2018 during the "Wyoming Energy for You" course to high school students from around Wyoming. In conclusion, utilizing these innovative hands-on teaching tools inspired the upcoming petroleum engineers and K-12 students and matched their diverse learning styles. The results of this study encourage petroleum engineering instructors to utilize more of these innovative teaching tools in their challenging courses and K-12 outreach events.

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