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Overview of Petroleum Engineering for Geoscience and Engineering Majors

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ABSTRACT

An overview of petroleum engineering has been designed for students with technical backgrounds, such as geology and engineering majors. We have adopted a research based, active learning pedagogy to engage students and achieve learning objectives. The pedagogy, course description, and student feedback are provided in this article.

Introduction

An overview of petroleum engineering has been taught to engineering and geology students. The student populations are kept separate by offering similar content in two different courses. Our focus here is the engineering version of the course entitled Petroleum Reservoir Management. The overview is suitable for students with an interest in a career in the energy industry, such as the oil and gas industry, or the geothermal industry. In our case, the engineering students are general engineering students with a focus on either mechanical engineering or electrical engineering. Students have the opportunity to become familiar with important concepts and techniques needed to manage fluid flow in reservoirs. Before discussing details of the course, we provide a rationale and description of the pedagogy used in the course.

Application of Pedagogy to Overview of Petroleum Engineering for Engineering Students

The overview of petroleum engineering presented in the Petroleum Reservoir Management course is designed for technical students that are not majoring in petroleum engineering. Most students taking this course are seeking conceptual understanding and exposure to modern petroleum engineering. Many have an interest in learning more about the oil and gas industry as a career opportunity. The primary goal of using research based pedagogy in this course is to encourage active learning by engaging students with the subject. Another course entitled “Energy in Society for the General Student Population” also used this pedagogy [Fanchi, 2016]. The Appendix presents a review of a few concepts for facilitating retention, and a discussion of Wieman’s [2007] research based pedagogy. Two benefits of using Wieman's pedagogy are summarized by the first two rows in Wieman's Table 1. Research-based instruction, particularly active learning, should improve the retention of information and the gain in conceptual understanding. Students are expected to learn from assigned reading and outside activities, and to spend up to 2 hrs studying outside of class for each hour of contact time.

Table 1. Comparison of Learning Results from Traditionally Taught Courses and Courses Using Research-Based Pedagogy [Wieman, 2007]	
Traditional Instruction	**Research-Based Instruction**
Retention of information from lecture: 10% after 15 minutes	Retention of information from lecture: More than 90% after 2 days
Gain in conceptual understanding: 25%	Gain in conceptual understanding: 50-70%

Course Description

Modern petroleum reservoir management relies on teams of people from a variety of scientific and engineering disciplines. This course introduces concepts and terminology for topics that are often encountered by members of petroleum reservoir management teams. Table 2 shows the topics covered and the order of presentation. The first two topics place oil and gas into a global context. Topics 3 and 4 provide essential background in fluids and porous media. The geoscience topics geology and geophysics place the reservoir in its geologic setting and show students how we develop a concept of a subsurface environment. The remaining topics focus on petroleum engineering beginning with drilling and completions and ending with reservoir engineering and reservoir management. Topic 12 is an optional topic that can include a computer lab activity if time permits. In many cases, interaction and feedback from students during the term indicates that more time be allotted to one or more of topics 1 through 11 to ensure adequate understanding of the material before continuing to the next topic.

Table 2. Course Topics	
Topic #	**Topic**
1	Introduction
2	The Future of Energy
3	Fluid Properties
4	Rock Properties
	Exam 1
5	Geology
6	Geophysics
7	Drilling and Completions
8	Surface Facilities

	Exam 2
9	Well Logging
10	Transient Well Testing
11	Production Evaluation Techniques
12	Reservoir Flow Modeling
	Final Exam

The 3 semester hour course is an elective that provides an opportunity for students to learn more about petroleum reservoir management. The student demographic is primarily general engineering students with a focus in mechanical engineering, and geology students. The course is used by many students in partial fulfillment of the requirements for a major in Engineering. Learning objectives include understanding system design; understanding how different disciplines contribute to development of petroleum reservoir systems; and developing skills for solving problems. Engineering students are expected to be juniors or seniors in the engineering major.

The content of an overview course is determined by a series of decisions that narrows the range of content to an amount that can be covered at a suitable level in a given time frame. Some of the content can be modified based on student interest determined by oral or written feedback at the beginning of the semester. In other words, ask the students what they would like to learn. In many cases the material is already part of the prepared content.

Classroom Management

Lectures using powerpoint presentations are combined with activities that are designed to engage the student. Short video clips, animated slides, and activities are interspersed in the lectures so that lecture segments are limited to approximately 15 minutes. Activities are often the basis for exam questions, which further encourages students to take careful notes on how to solve the problems. In-class activities may require individual work, or small group work. Exercises and problems can be solved using pre-calculus mathematics which is typically required of college students.

Homework activities include end of topic true/false activities, and a mixture of exercises that require active student involvement. Homework activities are worked in class so all students can check their solutions and, in many cases, discuss their approach to problems. Immediate feedback following in-class activities and feedback on homework is designed to help guide student thinking.

The text for the course [Fanchi, 2015] is customized to the course so that readings, homework, lectures, and in-class activities are closely aligned and complementary. A version of the text is scheduled for publication in 2016 [Fanchi and Christiansen, 2016]. Students are given an activity that requires them to make a walking fieldtrip to a nearby outcrop as part of the geology topic. When the opportunity arises, in-class guest speakers and relevant on-campus talks are assigned as activities. These opportunities are treated as extra credit if they arise at times that do not coincide with class time.

Student Assessment

Students are graded on participation and three exams. The scheduling of exams is shown in Table 2. Participation includes attendance and all assignments other than exams. Exams typically contain three sections:
1. True/False
2. Exercises requiring relatively simple calculations
3. Problems requiring more involved reasoning and more steps than exercises

Some students have conceptual problems (e.g. understanding of a concept or what unit should be used in a particular context) that can often be found by asking a range of questions and true-false statements. The exercises typically test student knowledge of quantitative terms, such as the difference between water-oil ratio and water cut. Problems assess more involved issues, such as estimating original gas in place for a depletion drive gas reservoir or determining the radius of investigation for a pressure buildup test.

The exams are open book/open notes tests in a timed setting. Students need to be familiar with the material and understand how to identify and solve problems to complete the exams in the time allowed. Another point to note is that open book tests with time limits minimize ethical issues (e.g. copying) and allow questions and problems on any aspect of the material that has been presented in class or in the assigned reading. It is not unusual to see that students have heavily annotated their textbooks and course notes in preparation for taking tests. This work has to be done outside of class, and is evidence of student engagement.

Activities, homework, lectures and exams are designed to assess student knowledge of fact-based material and skills associated with desired course outcomes. In this sense, “teaching to the test” means designing lecture and non-lecture material so that students are prepared to demonstrate their level of knowledge and skills on the exams. Each exam is an opportunity to further reinforce desired outcomes. The final exam is a comprehensive exam so that students must review course content for the entire semester. Student feedback (see Discussion below) showed that students recognized that open book/open notes tests were an effective way to assess student learning of the range of material covered.

Discussion

Students in a recent class (Fall 2015) were asked to provide feedback in response to the following questions:
1. What is working well for you with regard to this class?
2. What are your concerns – what would improve this class?
The class included 27 students, and 25 out of the 27 students were in attendance and responded to the questionnaire. Although the responses listed below represent one class, they are typical of student responses from other classes. Student responses from the Fall 2015 class to question 1 – what is working well for you – are organized by content and summarized below.

RELEVANCE

- Learning interesting and important information that can be used in our future careers. Important to how the world is changing today.
- The course is an overview of multiple disciplines and does an excellent job giving a class participant both a summary and comprehensive overview. The diagrams and lectures are fantastic.
- I like the subject matter. I am hoping to go into the oil and gas industry myself.

MATERIALS

- I enjoy watching videos of the things we learn about in the real world.
- Lecture notes
- The powerpoints are a nice complement to the textbook material
- Bringing in different rocks and devices used.

ACTIVITIES and HOMEWORK (HW)

- Working problems through class and going through examples.
- I really like the activities. They help out a lot for the tests.
- Class activities are interactive and helpful.
- The in-class problems help the most when it comes to getting comfortable with the equations.
- HW and doing the HW problems in class the day they are due so we can see how they are worked out.
- I like the way the HW is split up where everyone does a HW problem; it helps me learn better
- Doing the HW and reviewing the powerpoints really help me understand the material and test.
- Doing activities together in class to look more at real world applications

TESTING

- The tests are very fair and are based on classwork.
- Having the test problems be very similar to the book problems. Working problems out on the board.
- Open book tests. There is a ton of info in this class and many equations/formulas. Open tests allow students to show that they know how to use the material without having to memorize endless equations.
- There is a massive amount of information to know for tests – having it be open book is life saving
- A lot of information to handle for closed book.
- Testing, problems aren't too tricky but still make you work for them being an open-book exam.
- The open note/book tests make learning easier.
- Test problems being like the HW is nice, makes studying easier.

Student responses to question 2 – what would improve the class – focused primarily on the balance between lecture and non-lecture activities. As a rule, students preferred more classroom time allotted to non-lecture activities and less time allotted to lecture. One suggestion was to assume that students had completed outside reading so lectures could be shortened.

Two questions (3 and 4) addressed student preference for a specific pedagogical technique. The questions and preferences follow:

Question	**Preference**
3. What would you prefer (circle 1)? A. Activities like we've been doing in class or B. A weekly quiz based on assigned homework	 Prefer A: 20 Prefer B: 5
4. What would you prefer (circle 1)? A. Open book/open notes test B. Closed book test	 Prefer A: 24 Prefer B: 1

A few students (20%) preferred a weekly quiz based on assigned homework, while a significant majority (80%) preferred non-lecture activities. In addition, students clearly preferred open book/open notes tests. Reasons for the preferences are given in the student comments presented above.

Conclusions

The Overview of Petroleum Engineering course entitled Petroleum Reservoir Management is designed for engineering majors that are not majoring in petroleum engineering. The course uses a research based, active learning pedagogy to engage students and achieve learning objectives. The course is suitable for a variety of STEM majors, such as geology, geophysics, and mechanical, electrical, environmental and chemical engineering. It gives STEM majors a technical introduction to the technology needed to manage subsurface resources. Student feedback tended to support course content and pedagogy.

References

Bacon, D. R., & Stewart, K. A. (2006), "How fast do students forget what they learn in consumer behavior? A longitudinal study," Journal of Marketing Education, 28(3), 181-192.

Conner, J.V. (1991), "What Research Says to the Science Teacher -- The Process of Knowing," 6, Natl. Sci. Teachers Assoc., Wash. D.C.

Fanchi, J.R. (2015), **Introduction to Petroleum Engineering**, course notes.

Fanchi, J.R. (2016): "Energy in Society for the General Student Population," to be presented at the 2016 ASEE Gulf-Southwest Section Annual Conference, TCU, Fort Worth, March 6-8, 2016.

Fanchi, J.R. and R.L. Christiansen (2016), **Introduction to Petroleum Engineering**, Wiley, to be published.

Laird, T. F. N., Shoup, R., Kuh, G. D., & Schwarz, M. J. (2008), "The effects of discipline on deep approaches to student learning and college outcomes," Research in Higher Education, 49, 469-494.

Wieman, C. (2007), "Why Not Try a Scientific Approach to Science Education?" Change Magazine, Sep/Oct, 9-15.

Wieman, C., Perkins, K. and Gilbert, S. (2010), "Transforming Science Education at Large Research Universities: A Case Study in Progress," Change Magazine, Mar/Apr, 7-14.

Appendix: Pedagogy Primer

A review of a few concepts for facilitating retention, and a discussion of Wieman's pedagogy [2007] are presented here.

Facilitating Retention

Laird, et al. [2008] describe two types of learning: surface learning, and deep learning. Surface learning focuses on the substance of information. It emphasizes rote learning and memorization techniques. By contrast, deep learning integrates and synthesizes information with prior learning in ways that become part of a student's thinking. The student learns to approach new phenomena from different perspectives.

Bacon and Stewart [2006] recommend the development of a pedagogy that emphasizes deep learning. Some deep learning techniques include active learning exercises, team-based learning, and experiential learning. Deep learning may require sacrificing breadth of exposure for depth. The authors argued that topics that are not covered in depth are not meaningfully retained. More time is needed to process unfamiliar information than familiar information. An argument in support of discussing a broad range of topics is that one or more of the briefly discussed topics may make a special connection with a student.

Laird, et al. [2008] made the following recommendations:

A. Course prerequisites should be taken immediately before the course so that pre-requisite material is fresh.

B. Provide relevance to course content. For example, focus course content on concepts and tools that students will encounter in their first job.

C. Use cumulative exams. Although not a popular practice, repeated exposure to material improves retention. It is possible to improve student acceptance of this practice by pointing out the benefits of cumulative exams and helping students learn how to prepare.

Research Based Pedagogy

Wieman [2007] concluded from a study of science education research that effective teaching consists of engaging students, monitoring their thinking, and providing feedback. He observed that people learn by creating their own understanding. Effective teaching facilitates the creation of understanding by engaging students to think deeply about the subject at an appropriate level. The teacher monitors that thinking so it can be guided to be more expert-like.

Novices and experts view information differently. Learning is facilitated when people see a meaningful pattern in the information they are learning. For example, the series “17761812186119171945” is easier to remember as the historical dates “1776 1812 1861 1917 1945”. Conner [1991] refers to the conceptual framework formed by novices as a “naïve” conceptual framework because it is based on personal experience with little or no formal training in alternative viewpoints. The naïve conceptual framework may persist, even after formal instruction, if the novice’s perspective does not change.

Wieman [2007] observes that novices see course content as isolated pieces of information that are handed down from authorities and learned by memorization. Problem-solving is an attempt to match the pattern of the problem to a set of memorized recipes. By contrast, experts see their discipline as a coherent structure of concepts established by observation and experiment. They solve problems using strategies that are systematic, concept-based, and widely applicable. Experts have a larger knowledge base than novices and can better appreciate interconnections between knowledge and associated implications. Consequently, experts tend to organize information using a more sophisticated set of underlying criteria than novices.

Classroom learning can be improved by incorporating desirable cognitive activities into normal course activities. He suggested some tactics to reduce cognitive demand. Research has shown that short-term memory has limited capacity, so the cognitive load commonly associated with traditional lectures can be reduced by being more selective about what material is covered in class. Class organization should be clear and logical. Connections should be made between ideas presented in class and with things students already know. It is important to recognize that students have different learning styles, that is, different approaches to new material. Consequently, the use of a variety of teaching techniques and media can help a more diverse group of students connect with the material. Technical terms should be defined and used in the proper context. The use of technical jargon should be minimized.

Student thinking can be stimulated by providing in-class and homework activities that require active student thinking (involvement) and processing of important ideas. Immediate feedback following in-class activities and feedback on homework can help guide student thinking. An effective way for students to get feedback in large classes is peer collaboration. Wieman, et al [2010] discuss methods of implementing research based science education in large classes.