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Adrienne Minerick is an Associate Professor of Chemical Engineering at Michigan Tech having moved from Mississippi State University in Jan 2010, where she was a tenured Associate Professor. She received her M.S. and Ph.D. from the University of Notre Dame in 2003 and B.S. from Michigan Technological University in 1998. Adrienne’s research interests include electrokinetics and the development of biomedical microdevices. She earned a 2007 NSF CAREER award; her group has published in the Proceedings of the National Academy of Science, Lab on a Chip, and had an AIChE Journal cover. She is an active mentor of undergraduate researchers and served as co-PI on an NSF REU site. Research within her Medical micro-Device Engineering Research Laboratory (M.D. ERL) also inspires the development of Desktop Experiment Modules (DEMos) for use in chemical engineering classrooms or as outreach activities in area schools. Adrienne has been an active member of ASEE’s WIED, ChED, and NEE leadership teams since 2003.
Use of HiPeLE Approach in a Split-Level Chemical Engineering Elective Course

Abstract

High Performance Learning Environments (HiPeLE) are ones that are learning-centered, knowledge-centered, assessment-centered, and community-centered. These environments compliment the attributes of millennial generation students. Within such a learning environment, students are able to critically explore new concepts and link them to their prior knowledge pool. This approach was adapted in a combined undergraduate / graduate level special topics course on Analytical Microdevice Technology. This course was taught for the first time at Michigan Technological University although it had been prepped and taught at another institution two years before. The dominant themes of the course varied considerably between the two institutions primarily because the content was in large part student driven. Due to the highly applied nature of the curriculum, the parallels between large-scale unit operations and microscale unit operations (µUO) became a theme in the 2010 implementation of the course. Students interpreted existing microdevices from this perspective and in their semester-long project identified and expanded upon existing µUO. The community level discussions helped alleviate misconceptions such that the students were able to synthesize concepts from existing microdevice technology reported in the literature into their own novel concept development project. Assessment of the effectiveness of this approach is included.

Introduction

A special topics course on Analytical Microdevice Technology was designed and implemented at two different institutions. The course content evolved considerably from the first time the class was taught to the second time the course was taught in order to capture the substantial gains in technology and research approaches that have occurred over the two years between course offerings. A description of the content in the first offering of this course and four class activities were discussed in a paper in Chemical Engineering Education. In addition, the initial implementation of HiPeLE inspired concept development projects were described in an ASEE-SE proceedings paper. This paper describes and presents evaluations of the high performance learning environment in the second implementation of this course.

Course Structure with HiPeLE Component

This class met on Monday, Wednesday, and Friday with a designated task for each day of the week. The professor lectured on Monday, Wednesday was an interactive Survivor game, and Fridays were dedicated to student-centered discussions of archival journal articles. Outside of class throughout the semester, students were grouped into teams engaged in concept development projects. In order to capture the current state of the field, course content was largely student-centric and student-driven. This was accomplished via two main mechanisms; 1) student presentations and discussion of archival journal articles, and 2) a semester-long project that was student-invented and whose novel concept evolved over the course of the semester. In order to develop a design for a function driven microdevice, the students had to research...
electrokinetics and other technologies with the capabilities of performing the physical tasks needed for the microscale technology.

The content from one activity was intended to influence the content in other activities. For example, Friday article discussions were intended to act as a source of ideas for the concept development projects and were also used by the professor to guide what lecture content should be the subsequent week. For example, if an article chosen by the student to present on Friday was difficult to understand because fluorescence was extensively utilized, then the professor gave a foundational lecture on fluorophores, absorbance, emissions, quantum yield, equipment, and implementations. Content from lectures and articles were included in the Survivor questions asked on Wednesdays. In this way, the classroom embodied a High Performance Learning Environment. Further, the student concept development projects were highly learning-centered, knowledge-centered, and community-centered. Students were provided assessments of their learning progress and product output via correct / incorrect answers during the Survivor game, but the primary feedback was given with the Concept Development Projects (described in the next section). Within such a learning environment, students are able to critically explore new concepts and link them to their prior knowledge pool.

Concept Development Projects

The primary HiPeLE component in this course was a cooperative learning project whose subject was almost entirely driven by the students on the team. The semester-long exercise was structured to allow students to develop a researchable concept via independent reading, discussion, and mini-lectures.

Many proponents in diverse fields have advanced problem-based learning as a technique for students to learn to locate resources and teach themselves and each other concepts in the process of solving a central problem. The merits of this are based on the premise that traditional problem solving conducted in the classroom has the teacher posing a well thought out problem for the students to approach in a fashion that has been demonstrated by the professor in lectures or in examples. Substantial groundwork has already gone into the problem to determine if it is feasible, what tools will be needed to solve the problem, and that the necessary information is readily available for the students. However, once these students enter the workforce or graduate school, they are unlikely to encounter tasks of this nature. If a supervisor has gone to the trouble to define a problem with that level of precision, that supervisor has nearly completed the task and will certainly continue to complete it. Therefore, disconnects exists between the skills students need and the skills students are acquiring in traditional classrooms. HiPeLE classrooms strive to rectify this disconnect.

A secondary theme in the course was the integration of the current research knowledge in analytical microdevice technology into the chemical engineering education of undergraduate and graduate students. Many sources speak to the interrelatedness of research and education and the need to engage all students in research and discovery-based learning. The NSF and NRC urge that “students have access to supportive, excellent undergraduate education and that all students learn these subjects by direct experience with the methods and processes of inquiry.” The need to employ research as a pedagogical tool in undergraduate education is also the cornerstone of several publications and innovative programs that have been successful at training students to formulate hypotheses and perform original research at the undergraduate and graduate level.
The concept development project in this course engaged students in the experience of starting with a broadly defined idea, seeking information from the archival journal literature to limit that idea into a well-defined problem, and then proposing a viable microdevice design with suitable unit operations technologies to approach that problem. Progress reports were due from the student teams roughly every two weeks during the semester. The professor extensively edited these documents providing feedback on the feasibility of technology / approaches that the students chose in their design. When student groups had linked two concepts without sufficient evidence or their logic for the linkage was week, this feedback was provided back to them as well such that they could return to the topic, study it and address the weaknesses. One theme within this implementation of the course was drawing analogies between the traditional unit operation equipment at the macroscale with the microscale equivalents.

Assessments

Students were asked to provide feedback on the high performance learning environment in this course. A copy of the survey is included in Appendix A. Student consent was obtained and the survey was approved by the Michigan Technological University IRB for the protection of human subjects.

The survey was broken into four sections: Part A: Attitudes and Time, Part B: The High Performance Learning Environment Model, Part C: Reading, critiquing and assimilating information from archival technical journal articles, and Part D: Knowledge and Application of that Knowledge. The survey was conducted in the final class period of the semester. Four graduate students and four undergraduates were enrolled in the course. Six students voluntarily completed the survey (4 undergrads, 2 graduate students). Figure 1 captures the average responses and compares them to graduate students and undergraduate student responses.

In Part A: Attitudes and Time, students were asked their feelings toward the class (Q1) to assess if they felt the course had been a good use of their time. On average, students felt that it was a good use of time (4.2) with graduate students rating it (4.5) closer to 5= ‘I’m very glad I took it!’ than undergraduates (4.0) with 4 = ‘It was a good use of time.’ Question 2 asked about the student’s exiting attitude in the course and the average for this was 4.7 much closer to “This course helped guide me to learn essential skills that will or has already made me better / more productive as a student / professional” than “This course provided some skills / knowledge that I will use.” The average for graduate students was 5.0 while that for undergrads was 4.5. On average, the students said they spent 6 to 10 hours per week on the class (Q3) without much difference between that reported by graduate and undergraduate students.
Figure 1: Average responses alongside graduate student and undergraduate student responses to the survey questions provided in Appendix A.

In Part B: The High Performance Learning Environment Model, students were provided a definition of a HiPeLE class and then asked questions about the implementation of it in this course. When asked if the students found they were heavily influencing content in the course (Q5), students agreed with this (4.0) with graduate students much closer to neutral (3.5) and undergraduates between agree and strongly agree (4.3). When asked if the professor or they were more in charge (Q6), students overall felt they were somewhat in charge (4) with graduates feeling more empowered (4.5) than undergraduates (3.7). When considering all course activities, the students felt the professor acted as a facilitator between 50% and 75% of the time (Q7) with graduate students responding much higher than undergrads. Compared to a traditional lecture course, the students agreed that the HiPeLE environment was more stressful (Q8=3.8). In response to the query whether the HiPeLE course felt less organized, students rated this a 3.5 close to the neutral range. When asked whether HiPeLE increased their learning (Q10) over a traditional lecture class, students overall were relatively neutral (3.3) while graduate students rated closer to ‘I learned more in this HiPeLE course’ (3.8) than undergrads who tended toward, “I would have learned more in a lecture course’ (2.5). The last question in this section asked about which format the students enjoyed (Q11). Overall, the rating was slightly toward enjoying HiPeLE better (3.3) with graduate and undergrads largely in agreement (3.5 and 3.3 respectively).

In Part C: Reading, critiquing and assimilating information from archival technical journal articles, the students were first asked to judge how much information they learned from archival
journal articles before (Q13), during (Q14), and predict after (Q15) this class. Averages were before = 3.2 corresponding to ‘24-10% of what I learned was from the literature’, during = 4.8 which corresponds to ‘>50% of what I learned was from the literature’, and after = 4.2 which is a percentage of 25 to 49%. Graduate students, as expected rated this higher than undergrads with before =5.0 and 2.3 where 2 corresponded to 1-9%, during 5.0 and 4.8, and after, 5.0 and 3.8, respectively. When asked if the course demonstrated the value of peer-reviewed literature, graduate and undergraduate students were in perfect agreement of 4.5 halfway between strongly agree and agree. In Q17 and Q18, students were also asked their experience reading the journal articles before the class (average was 2.7) and then at the completion of the class (average was 3.3). Graduate students didn’t rate their experience to have changed (3.0), but undergrads increased from 2.5 to above graduate students at 3.5, which was a rating of sufficient / proficient.

In Q19 and Q20, when asked if they had experience compiling literature on a subject, organizing it logically, and presenting it to others in a manner that showed progression of knowledge, overall responses were relatively neutral (3.3), but this increased by the end of the class to 3.8 (close to doing it independently with only some guidance). Graduate students stayed at 4.0 over time, but undergrads increased from 3.0 to 3.8. Lastly, students were asked if they had experience writing research articles combining these skills (Q21) and the result was 3.8 indicating they could structure a complete first draft, but would need guidance refining to final draft.

The last section of the survey was Part D: Knowledge and Application of that Knowledge which started off by asking what the students perceived their foundational knowledge to be (Q23). Students largely rated this Good / Sufficient (3.0) with graduate students rating this substantially lower (2.5) towards Fair (I struggle, but can figure most things out) compared to undergraduates (3.3) who tended slightly toward Very Good (I could carry on a lengthy discussion with my professors). When asked if learning about the microscale and unit operations in microchannels helped them expand their understanding of chemical engineering (Q24), the average rating was 4.2, slightly greater than agree with graduate students halfway between agree and neutral (3.5) and undergraduates halfway between agree and strongly agree (4.5). When asked to rate their skill set in developing a microdevice design (Q25), both levels of students agreed they could do this with some guidance (3.0). In Q26, they rate their ability to describe a detailed method of approach, description of the device, and operation as 3.2 just above completing this with some guidance. Graduate students were slightly more confident (3.5) than undergraduates (3.0). Next, students rated their ability to contextualize the importance of this within the larger research field (Q27) as 3.3 with graduate students halfway to being able to do it as well as their professors, just taking longer (3.5). Lastly, the students were asked to reflect back on their skills at the beginning of the course and compare them to the end of the course when they completed the survey (Q28), the average felt they were somewhat better now (4.2) with graduate students landing halfway between ‘no change’ and ‘somewhat better now’ at 3.5 and undergraduates being between ‘much better now’ and ‘somewhat better now’ at 4.5. This ties back into the first question which asked if the students thought the class was a good use of their time, which a majority did.
Conclusions

This paper outlined the implementation of concept development projects in a HiPeLE format in a split level special topics course on Analytical Microdevice Technology. Structure of the projects and the course were discussed in order to contextualize and guide the reader on implementing a high performance learning environment. Assessment was conducted of the students to ascertain their thoughts and feelings on driving and directing their own learning. The results were tracked for the entire class as well as for graduate students and undergraduates.

The assessment results were particularly interesting. The comparison between graduate student responses and undergraduate student responses illustrated that the HiPeLE model is more conducive to graduate student learning than undergraduate student learning and that the comfort level of graduate students is greater in a course of this type. However, when asked to assess their own skill set and knowledge, undergraduates rate themselves higher than graduate students suggesting they have a higher opinion of their abilities possibly because their perspective of the field of chemical engineering has been so carefully packaged for them. The greater discomfort (relative to graduate students) they experienced with the HiPeLE format may be due to the deviation from this nice packaging of content.

References:

Appendix A: Post-course Assessment Survey

Undergraduate or Graduate student?_______________________

Part A: Attitudes and Time:

1. Now that you have completed the course, what are your feelings toward the class?
   a. I’m very glad I took it!
   b. It was a good use of time
   c. Neutral
   d. It wasn’t a good use of my time
   e. I really wish I hadn’t taken this class!

2. What is your exiting attitude toward this class?
   a. This course helped guide me to learn essential skills that will or has already made me better / more productive as a student / professional
   b. This course provided some skills / knowledge that I will use
   c. Neutral
   d. I didn’t learn important skills or knowledge
   e. I didn’t learn anything that will benefit me in the future.

3. On average, I actually spent the following hours per week on this class
   a. Less than 5
   b. 6-10
   c. 11-15
   d. more than 15

4. Please feel free to comment on questions 1 through 3 (Part A):

Part B: The High Performance Learning Environment (HiPeLE) Model

High Performance Learning Environments (HiPeLE) are ones that are designed to place students in charge of learning. The instructor becomes a facilitator that only periodically steps in to guide the content in the course.

5. As a student, I found I was heavily influencing content in this course.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree
6. What fraction of in class time (MWF 2 to 3) did you recognize the professor acting as a facilitator?
   a. I was very much in charge of my learning & content in the course
   b. I was somewhat in charge
   c. Students / professor equally in charge
   d. Professor somewhat in charge of content
   e. Professor totally in charge of content

7. When considering total course activities, what fraction of time would you categorize the professor as a facilitator?
   a. 100%
   b. 75%
   c. 50%
   d. 25%
   e. 0%

8. Compared to traditional lecture courses, what was your stress level in this HiPeLE course?
   a. Much greater than lecture course
   b. Greater
   c. Same
   d. Less than
   e. Much less than lecture course

9. Previous students have commented that HiPeLE courses are less organized. To what extent do you agree or disagree with this?
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree

10. High Performance Learning Environments are intended to increase student learning. Compare to a traditional lecture class and rate which environment you would have learned more.
    a. I learned much more in this HiPeLE course
    b. I learned a little more in this HiPeLE course
    c. I learned about the same as I would have learned in a lecture course
    d. I would have learned a little more in a lecture course
    e. I would have learned much more in a lecture course

11. As a student, I enjoyed this format better than traditional lecture courses.
    a. Strongly agree
    b. Agree
    c. Neutral
    d. Disagree
    e. Strongly disagree

12. Please comment on anything that influenced your answers in 5 through 11 (Part B).
Part C: Reading, critiquing and assimilating information from archival technical journal articles.

13. **BEFORE** taking this class, the amount of information I learned from archival literature (or other peer-reviewed sources) was:
   a. > 50% of what I learned was from archival literature
   b. 49 – 25% of what I learned was from archival literature
   c. 24 – 10% of what I learned was from archival literature
   d. 9 – 1% of what I learned was from archival literature
   e. Zero, zip, nada, nothing

14. **DURING** this class, the amount of information I learned from archival literature was:
   a. > 50% of what I learned was from archival literature
   b. 49 – 25% of what I learned was from archival literature
   c. 24 – 10% of what I learned was from archival literature
   d. 9 – 1% of what I learned was from archival literature
   e. Zero, zip, nada, nothing

15. **AFTER** taking this class, the amount of information I expect to learn from archival literature (or other peer-reviewed sources) will be:
   a. > 50% of what I learned was from archival literature
   b. 49 – 25% of what I learned was from archival literature
   c. 24 – 10% of what I learned was from archival literature
   d. 9 – 1% of what I learned was from archival literature
   e. Zero, zip, nada, nothing

16. This course demonstrated to me the scientific value of peer-reviewed literature versus journalists reporting.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree

17. **BEFORE** taking this class, please rate your experience at reading archival journal articles as:
   a. Very proficient (can read / skim it once and understand all)
   b. Proficient (can read closely once and understand all)
   c. Sufficient (can understand most after rereading closely)
   d. Inefficient (can understand some after rereading closely)
   e. Very inefficient (understand little after much rereading)

18. **At this moment, I would rate my experience at reading archival journal articles as:**
   a. Very proficient (can read / skim it once and understand all)
   b. Proficient (can read closely once and understand all)
   c. Sufficient (can understand most after rereading closely)
   d. Inefficient (can understand some after rereading closely)
   e. Very inefficient (understand little after much rereading)
19. **BEFORE** taking this class, I had experience compiling a survey of the literature on a subject, organizing it logically, and presenting it to others in a manner that showed progression of knowledge.
   a. Strongly agree (I can do this independent of guidance)
   b. Agree (Can do some independent, need some guidance)
   c. Neutral (Need guidance, can follow instructions)
   d. Disagree (Need guidance, sometimes need repeat to follow instructions)
   e. Strongly disagree (Never thought about it)

20. **At this moment,** I would rate my experience compiling a survey of the literature on a subject, organizing it logically, and presenting it to others in a manner that shows progression of knowledge as:
   a. Outstanding (I can do this independent of guidance)
   b. Great (Can do some independent, need some guidance)
   c. Good (Need guidance, can follow instructions)
   d. Ok (Need guidance, sometimes need repeat to follow instructions)
   e. Weak (please don’t make me do this!)

21. I have experience writing research articles that combine the skills from 11 through 14.
   a. Strongly agree (I can do this independent of guidance)
   b. Agree (Can structure a complete first draft, need guidance refining to final draft)
   c. Neutral (Need guidance structuring first draft, guidance refining to final draft)
   d. Disagree (Need guidance on some sections and guidance on first through final drafts)
   e. Strongly disagree (Need guidance on each section and step by step approach)

22. Please comment on anything that influenced your answers in 13 through 21 (Part C).

**Part D: Knowledge & Application of that Knowledge**

23. **I would rate my foundational knowledge in chemical engineering as:**
   a. Excellent (at the same level as my professors)
   b. Very Good (I could carry on a lengthy discussion with my professors)
   c. Good (I’m sufficient)
   d. Fair (I struggle, but can figure most things out)
   e. Poor (I’m lost a good portion of the time)

24. **Learning about the microscale and unit operations in microchannels helped expand my understanding of chemical engineering.**
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly Disagree
25. I would rate my ability to develop a well-defined design and relate concepts from archival literature as:
   a. I could do this as well as my professors without any guidance
   b. I could do as well as my professors, but it would take me longer
   c. I could do this with some guidance
   d. I’d struggle, but could possibly develop a design with major guidance
   e. I couldn’t do this at all

26. I would rate my ability to describe a detailed method of approach, description of the device, and operation as
   a. I could do this as well as my professors without any guidance
   b. I could do as well as my professors, but it would take me longer
   c. I could do this with some guidance
   d. I’d struggle, but could possibly do this with major guidance
   e. I couldn’t do this at all

27. I would rate my ability to contextualize the importance of this within the larger research field as:
   a. I could do this as well as my professors without any guidance
   b. I could do as well as my professors, but it would take me longer
   c. I could do this with some guidance
   d. I’d struggle, but could possibly do this with major guidance
   e. I couldn’t do this at all

28. Comparing the skills in 25 through 27 from the beginning of this course until this moment:
   a. I am much better now
   b. I am somewhat better now
   c. No change
   d. I am somewhat worse now (i.e. I was somewhat better in August)
   e. I am much worse now (i.e. I was much better in August)

29. Please comment on anything that influenced your answers to 23 through 28 (Part D):

30. Please provide feedback in any area that you think would improve this course next time it is conducted.