01 Oct 2008

Work in Progress -- Balancing Prescribed and Project-Based Experiences in Microfabrication Laboratories

Chang-Soo Kim
Missouri University of Science and Technology, ckim@mst.edu

Steve Eugene Watkins
Missouri University of Science and Technology, watkins@mst.edu

Recommended Citation

C. Kim and S. E. Watkins, "Work in Progress -- Balancing Prescribed and Project-Based Experiences in Microfabrication Laboratories," *ASEE/IEEE Frontiers in Education Conference*, Institute of Electrical and Electronics Engineers (IEEE), Oct 2008.
The definitive version is available at https://doi.org/10.1109/FIE.2008.4720380

Work in Progress - Balancing Prescribed and Project-Based Experiences in Microfabrication Laboratories

Chang-Soo Kim and Steve E. Watkins
Missouri University of Science and Technology, ckim@mst.edu, steve.e.watkins@ieee.org

Abstract - **Student education for microfabrication processes needs to integrate theoretical understanding with process understanding. Instructional challenges exist in designing effective laboratory experiences. The pedagogical issues include linking theoretical lecture concepts to cost-effective laboratories, tailoring the relative time between lectures and laboratories, and balancing the laboratory assignments between prescribed and project-based experiences. We describe the progressive implementations of microfabrication laboratory experiences in graduate courses. The first offering has no laboratory activity. The prescribed laboratory and project-based laboratory components were gradually incorporated. All laboratory experiences were team-based and utilized cost-effective facilities. The assessments indicate that students prefer significant laboratory experience and that learning of selected lecture concepts is enhanced through an interactive environment. Furthermore, observations are made concerning the effective balance of lecture and laboratories and of prescribed and project-based experiences.**

Index Terms – microfabrication; laboratory; microsystem; MEMS; project-based learning, teamwork.

INTRODUCTION

Microsystems or microelectromechanical systems (MEMS) technologies play a central role in many interdisciplinary applications. Microfabrication processes for implementing microsystems are fundamental aspects. Student education must integrate theoretical understanding with process understanding. Laboratory experiences are well-recognized means to enhance student motivation and to advance their high-level understanding of complex concepts and systems. However, instructional challenges exist in designing effective laboratory experiences with affordable budgets. The pedagogical issues include linking theoretical lecture concepts to cost-effective laboratories [1], tailoring the relative time between lectures and laboratories, and balancing between prescribed laboratory experiences and project-based experiences. For instance, the time constraints in a single-semester course require careful allocation of lectures, process experience, and project experience. In particular, project-based assignments become rote and frustrating without an adequate understanding of individual processes and related theories. This work describes the progressive implementations of microfabrication laboratory experiences in graduate courses to teach broad aspects of microsystem technology from individual processes to device characterization. All laboratory experiences were interdisciplinary team-based activities utilizing cost-effective equipment for photolithography, thin film deposition and etching (about $50,000 total).

IMPLEMENTATION OF LABORATORY EXPERIENCES

I. Adaptation of problem-based learning and interdisciplinary team strategies

The first objective in implementing the laboratory session was to incorporate problem-based learning (PBL) [2] with a balance between the prescribed laboratory elements (i.e. individual process practice) and the project-based laboratory activity. Recently, the integration of pedagogical theory with PBL activities was practiced and its effectiveness was investigated using microfabrication laboratory courses as a case study [2]. Improved attendance and average scores were observed after introducing the PBL method. It has been shown that the PBL method is effective in the teaching and learning process and can generally enhance those processes. However, proper integration with lecture elements and prior experience with component processes are necessary.

The second objective was to incorporate an interdisciplinary team-based laboratory activity. The area of microsystem technology is, by its nature, interdisciplinary. Current microfabrication technology is an area where a variety of disciplines interact to implement microsystems. This aspect provides students with a rich opportunity to practice better communication and teamwork skills. Interdisciplinary microelectronic processing courses have been developed and successfully introduced into various engineering curricula [3,4]. It was reported that the opportunity to work with students' colleagues from other discipline promoted their lateral thinking. It also turned out that human factors such as contributions from and respect for each team member and leadership from a team member played important roles in successful team activity. A more cooperative learning environment encourages interdependence and promotes better communication skills.

II. Progressive implementation of laboratory components

The graduate-level microfabrication course (EE 422: Integrated Microsystem Engineering) has been offered five times since 2003. The average enrollment size was 7.6 graduate students per class. The students participants (total 38) are from diverse disciplines including electrical (25), computer (5), materials (5), chemical (2), and physics (1). The lecture content consisted of: (A) individual processes such as photolithography, impurity doping, thin-film deposition, and etching; (B) introduction of foundry services such as Sandia National Lab and MUMPs processes; and (C) review of underlying principles and devices structures of various types of microsystems such as mechanical, optical, fluidic, and (bio)chemical devices. The first course was organized as a traditional 15-week lecture for one semester without laboratory components. After the course, most of the students' comments pointed out the lack of hands-on laboratory experiences.

From the next three offerings, the course was organized as a 10-week lecture session followed by a 5-week laboratory session devoted to prescribed experiences in individual processes. The lecture materials were reduced accordingly to focus more on core concepts. The course did not have parallel lecture/laboratory session. Therefore the students were familiar with theoretical knowledge necessary to conduct prescribed laboratory experiences. Each group practiced individual processes according to the prescribed laboratory instructions with help from a teaching assistant. While an improvement, this approach had limited opportunities for student interaction and design experiences.

The latest implementation had 8 out of 15 weeks devoted to a balance of prescribed and project-based experiences. Students with different disciplinary backgrounds were teamed in groups of 2 or 3. The main intent was the high-level understanding of complex concepts and systems through this project-based laboratory assignment. The first 2 weeks were devoted to learn individual processes demonstrated by a teaching assistant and to prepare a problem-based project proposal per group. Then the remaining 6 weeks were devoted to design, fabrication, and characterization of the devices. The average cost for each project was about $300.

PRELIMINARY ASSESSMENT AND CONCLUSION

After the last class offering, a survey was conducted to assess the effectiveness of our implementation. Among the survey questions, several important ones are listed below:

1. *I prefer a proposed project (by ourselves) than an assigned project (by instructor) for project-based laboratory experiences.*
2. *I feel that I experienced an interdisciplinary team activity.*
3. *I would recommend this course to other students.*

In addition, the student preference on the types of laboratory experiences among project-based, prescribed, and no laboratory options, and appropriate balance between lecture and laboratory sessions were questioned. The survey results are shown in Figure 1.

Overall, the preliminary assessments indicate that students prefer significant laboratory experience with project elements and that learning of selected lecture concepts is enhanced through an interactive and interdisciplinary environment. The students preferred the current balance of 7 weeks lecture to 8 weeks laboratory activities. Additional assessment and the role of laboratory and project documentation in student learning and satisfaction will be investigated in the next offering.

ACKNOWLEDGMENT

This work is supported partly by NSF (grant ECS-0644679).

REFERENCES

[1] Gowzdz, P., "NSF microfabrication workshops", *IEEE Transactions on Education,* Vol. 39, No.2, 1996, pp. 211-216.

[2] Cirstea, M., "Problem-based learning (PBL) in microelectronics", *International Journal of Engineering Education,* Vol. 19, No. 5, 2003, pp. 738-741.

[3] Muscat, A., E. Allen, E. Green, L. Vanasupa, "Interdisciplinary teaching and learning in a semiconductor processing course", *Journal of Engineering Education,* Vol. 87, 1998, pp. 413-421.

[4] Allen, E., S. Gleixner, G. Young, D. Parent, Y. Dessouky, *et al.*, "Microelectronics process engineering at San Jose State University: a manufacturing-oriented interdisciplinary degree program", *International Journal of Engineering Education,* Vol. 18, No. 5, 2002, pp. 519-525.

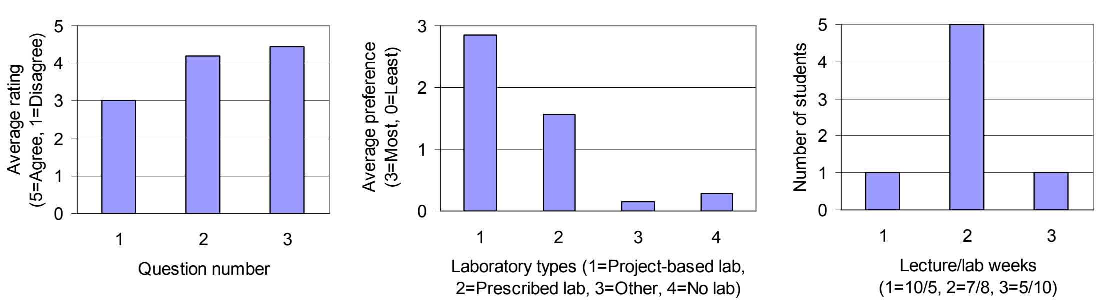

FIGURE 1
(A) AVERAGE RATINGS OF ANWERS. (B) PREFERRED LABORATORY EXPERIENCES. (C) PREFERRED BALANCE BETWEEN LECTURE /LABORATORY.