Session 1608

The Use of Student Portfolios in Biological Engineering Instruction

Ann D. Christy, Marybeth Lima
The Ohio State University/Louisiana State University

Abstract

The creation of individual student portfolios to document and enhance the learning process has been used with success in various teaching venues (e.g. architecture, fine arts and writing classes). However, the use of portfolios as a learning tool in biological engineering instruction has not been documented in the literature. Student portfolios were listed as a means of assessment under the basic level accreditation criteria for ABET Engineering Criteria 2000. Thus, its relevance as an engineering educational tool is recognized.

In this case study, student portfolios were assigned to students for two courses. The first was Agricultural Engineering 625 (AE 625): Modeling and Design of Biological Systems, taught by A.D. Christy at The Ohio State University. This required senior level course involved the application of transport processes, enzyme kinetics and simulation of plant and animal growth to the analysis and design of biological systems and processes. The second course was Biological Engineering 1252 (BE 1252): Biology in Engineering, taught by M. Lima at Louisiana State University. The objective of this required freshmen level course was to introduce the effects of variability and constraints of biological systems on engineering problem solving and design. In AE 625, portfolios were the primary instrument for evaluating learning, and were used to demonstrate mastery of core competencies identified in the course objectives. Core competencies were established through interviews with future employers and current professionals, and discussion between the instructor and the students taking the course. In BE 1252, portfolios were one of several instruments for evaluating learning, and were used to help students develop their ideas regarding their potential careers as biological engineers.

We have used student portfolios in an effort to initiate a student centered learning. To this end, we have incorporated interactive means, including interviews of practicing engineers, student presentations (oral and written), individual and group design projects, and site visits, while minimizing passive learning approaches such as lecture. The portfolio method encourages students to take greater responsibility for their own learning and makes explicit the life-long nature of engineering education. Our philosophy is that students, given more proactive roles in their own learning process, will better comprehend both biological engineering concepts, and their future roles as practicing biological engineers. In this paper, the methodologies for using portfolios are detailed, the results of applying the portfolio method as an assessment tool in biological engineering are presented, and recommendations for improvement are discussed.

Introduction

Overview. While student portfolios have long been used to document student learning and mastery in subjects such as art, writing, and architecture, their use in engineering education has been a relatively recent phenomenon. A literature search yielded nothing pertaining to student portfolios in biological engineering instruction, and little concerning portfolios in other engineering disciplines[1]. We used several references (detailed below) to aid the development of student portfolios as an instrument for learning and assessment for AE 625 and BE 1252. Because these two courses are still being taught at this time, partial results are reported in this paper. Full results will be presented at the meeting.

Cress and McCullough-Cress (1995) define a student portfolio as a systematic and purposeful collection of student goals for learning, works in progress, peer and instructor feedback, and reflection on the work and processes. The development of student portfolios for AE 625 and BE 1252 reflects this definition. Portfolios are a useful tool in assessing learning because they require students to review their work and create their portfolio by engaging in a process of reflection, selection, and description (Camp, 1990). The use of student portfolios as an effective means of assessment has already been established for those disciplines in which portfolios have long been used. The purpose of this paper is to describe and analyze the implementation of student portfolios in AE 625 and BE 1252.

Rationale: communication, synthesis, active learning, feedback. We used portfolios to address four current issues in engineering education. The first was communication skills; one common complaint from industry is that engineering graduates have adequate technical knowledge, but insufficient written and oral communication skills. Student portfolios were designed such that students had numerous opportunities to develop and practice these communication skills.

A second issue involved “levels of learning.” Loosely based on Bloom’s (1953) taxonomy and the Newcomb-Trefz (1987) model regarding the learning process, four levels of learning presented in ascending order are: (1) Information: the student can define, repeat, list, name, label, memorize, recall and/or relate to the information presented. (2) Knowledge: the student shows an understanding and comprehension of the information gained in level one, and can describe, explain, compare/contrast, identify, discuss and/or summarize it. (3) Application and analysis: the student solves problems by applying knowledge (level two) in new situations, and can critically distinguish the logical components of other applications of that knowledge. (4) Wisdom: the student displays professional judgment and the ability to synthesize, organize, plan, manage, teach and/or evaluate material from the first three levels. One major goal in using student portfolios was to permit students to concentrate on mastering subject matter at the two higher levels of learning.

A third issue was active learning. Non-lecture approaches such as discussion, case study, site visits, interviews, in-class assignments, student presentations, and design projects enabled students to be active participants in their own learning. Some assignments asked students’

---

[1] Internet and library searches were performed.

opinions regarding their thoughts, feelings, and progress as a result of having participated in them. Thus, students documented the success of these methods by means of the portfolio.

The final issue addressed was feedback; the re-submission process provided opportunity for students to improve on specific issues. In this manner, one can reward students for work well done and encourage them to improve on areas of weakness. While this aspect of portfolio design is time consuming for the instructor, dividends are paid to the student in individual attention and improved comprehension. This approach does not require students to seek out professors only if they have questions, it requires *all* students to participate in the process. As a result, students of all backgrounds and abilities are challenged to improve.

Course descriptions.

AE 625: Modeling and Design of Biological Systems. One of the senior level core courses in OSU's agricultural engineering curriculum, this course was described as the application of transport processes, enzyme kinetics, and the simulation of plant and animal growth to the analysis and design of biological systems and processes. After a brief review of basic principles of biology, microbiology, and biochemistry, units on enzyme reaction rates and models, material and energy balances for microbial cell cultures, batch growth and continuous flow reactor design, bioprocessing scale up, bioseparation operations, and modeling of plants, animals, and agroecosystems were covered. Applications were drawn from the food, agricultural, and environmental industries. Twenty-five students, including five graduate students, were enrolled in this course.

Assignments were divided into six categories: homeworks, laboratory reports, midterm exam, individual student presentations of biological engineering applications, team design project, and other optional items of the students' own choosing. Two approaches were used for the design project. Some students chose to work on a design project defined by the instructor; this year's topic was the biological treatment of landfill leachate and directly followed a leachate collection system design project many of the students had performed in conjunction with a local consulting firm during the prior quarter's soil and water engineering course. The second design project approach was for the students to choose their own biological engineering topic. Each student was required to complete one design project and make one class presentation during the quarter.

BE 1252: Biology in Engineering. The second of eight core courses in LSU's biological engineering curriculum, the description of this course was as follows: effect of variability and constraints of biological systems on engineering problem solving and design; engineering units; engineering report writing; oral report presentation; laboratory demonstration of biological engineering analysis. Thirty students were enrolled in this course.

BE 1252 consisted of two major units; the first focused on mastery of basic concepts (units, report writing, information searches, elementary data analysis). The second encompassed application of these concepts to the field of biological engineering, and to the class design project. Assignments were divided into three categories accordingly: (1) Examination of the student's motivation for choosing biological engineering as a major area of study. Self assessment instruments were used to accomplish this goal. (2) Study of the biological engineering field. This was achieved through field trips, case studies, Internet and library searches, in-class writing and discussion exercises, and interviews with faculty, staff, students, and practicing engineers. (3) Class design project. This semester long, guided exercise introduced students to the engineering method and attributes of design with regard to creating a new and/or improved cage for LSU mascot Mike the Tiger.

Fundamental information pertaining to tiger cage design was presented to the class as a whole, and observations of the tiger and the cage design were performed by the students individually. Students were then split into two types of groups, those working on improving the existing cage design, and those designing a new tiger habitat. Within groups, students were responsible for dividing the work load amongst themselves, and confidential peer evaluation among group members was an important component of each student's grade. Groups will be consolidated, and the final project will consist of two designs: an improvement of the existing cage and a new habitat design. A proposal to LSU administration for implementing these designs will be written by the class, and presented to a panel including members of the University Planning Committee, and tiger habitat experts.

Methodology

Implementation of the portfolio method.

AE 625. The portfolio method was implemented by having each student maintain a portfolio of their best work throughout the quarter. The contents of the portfolio were at the students' discretion, but each was required to include a cover page, a completed competency matrix (Figure 1), and a self assessment narrative. Three-ring binders with tabbed dividers were used to keep materials organized.

The competency matrix was derived through reviews of several textbooks on bioprocess engineering, interviews with future employers and current professionals, and discussion between the instructor and the students taking the course. Before the course began, two students were employed to interview practicing engineers. Approximately twelve interviews were conducted by phone and in person, and a list of perceived requisites for employment at entry-level bioengineering positions was generated. Students were invited to continue the interview process during the first two weeks of the course to further hone the list of core competencies. The final competency matrix generated from this process defined the course objectives and allowed students to assess their progress through the four levels of learning as they mastered each course element. This makes explicit that learning is not a binary operation of ignorance versus full knowledge, but a dynamic, progressive process. As the students progressed through the levels of learning for each competency element, they were to reference one or more examples of their work which demonstrated that they had achieved the stated level of mastery. These examples were drawn from completed assignments or any other items a student chose to undertake for this class. At the end of the quarter, each student was required to have achieved level three mastery in all competency areas, and level four in at least 10% of the elements. Additional competencies could be added by the student beyond those required, as long as they were demonstrated by referenced documentation in the portfolio.

The method of documentation was at the discretion of the student, but as the course progressed, the class requested more structure to select problems corresponding to the individual competency elements. Therefore, the instructor developed a problem set options sheet which listed the topics and competencies on the left two columns as in the competency matrix, and identified the corresponding assignments (homeworks, labs, midterm, and textbook problems) which dealt with each competency. The number of problems per competency ranged from one to twenty-three, and students were encouraged to do enough problems to demonstrate to themselves and to the instructor that they had mastered the competency element. Resubmission of each document was required until the goal of quality work was achieved. Quality was defined as meeting or exceeding instructor expectations (Langford and Cleary, 1995). This is equivalent to "A" quality work, which includes correct numerical answers but also demonstrates more thinking, more elaboration and insight, and better craftsmanship (McClelland, 1991). Feedback was provided throughout the course in the resubmission process, and the completed portfolio was worth 100% of each student's final grade. Those students who mastered the material in less than the ten weeks of the quarter were released from any further expectations for the class.

The third required component of the portfolio was the self assessment narrative, which included a short paragraph for each example contained in the portfolio, and a concluding summary paragraph in which the student reflected on her/his overall experience of the course. These paragraphs allowed the students to evaluate their own performance, and to identify areas of strength and areas needing improvement in biological engineering. The narrative was also intended as a reference for future contact with prospective employers and job interviews.

BE 1252. The portfolio method as applied to this class was more structured in nature than the method employed in AE 625. The instructor chose the assignments required for inclusion in the portfolio, and the student chose the method to organize and present this information. Self-assessment narratives for selected assignments were required, and a self-assessment narrative describing the students' experience with the course material and the portfolio was also required. While the learning matrix was central to portfolio development in AE 625, it was not used in developing the portfolio method for BE 1252. The instructor was responsible for designing the assignments such that learning levels three and four were included. This approach was chosen so that these less experienced students could concentrate on the content to be learned without carrying the additional responsibilities for assessing their own level of mastery of that content.

Assignments were graded and returned to the students as soon as possible. Upon receiving a graded assignment to be included in the portfolio, the student had one week to re-work that assignment if s/he deemed it necessary. Portfolios contained all attempts at individual assignments required for the portfolio. Students were encouraged to include additional thoughts, feelings, and insights gathered throughout the semester. The portfolio was presented to the student as a means of documenting the student's thought process in identifying his/her motivation for choosing engineering, investigating areas of interest within biological engineering, and learning fundamental concepts involving engineering design. The portfolio was interpreted by students as both a requirement for the course, and a method to help them in their quests to be engineers.

Portfolios were checked at mid-semester, and were evaluated based on completeness, organization, and creativity. The portfolio was worth 50% of a student's total grade. A midterm exam, a final exam, and other assignments not required for the portfolio comprised the other half of the student's grade. Participation was not a component of the student's grade for this course; effort was made to pull students into actively participating rather than pushing them with requirements.

Evaluating methods. In order to evaluate the effectiveness of the student portfolio method and the course, an exit survey was completed by each student. The same survey (with minor additions) was administered to each class, and consisted of the following questions:

1. How did this approach to teaching and learning benefit you?
2. How did this class compare with a lecture oriented class? Which approach is better and why?
3. What were the strengths and weaknesses of using portfolios in this class, and how can this system be made better?
4. Do you feel that the student portfolio method enhanced your learning and why?
5. What are the strengths and weaknesses of the instructor?
6. Was instructor responsive to midquarter/midsemester evaluations?
7. What topics did you like most and least? What other topics should be included?
8. Was the design project helpful for illustrating concepts involved in biological engineering?
9. Did the class meet your expectations?
10. What ideas from this course do you want to remember in ten years?

Other course evaluation methods used in the two classes included in-class discussions, student questionnaires, external interviews, and class committees. The in-class discussions led to revisions in the syllabi and consensus on grading policies. Standard institutional questionnaires (Student Evaluation of Instruction, or SEI forms) were distributed at the end of both courses, in addition to the more formative instructor-designed exit survey described above. A teaching consultant from OSU's Office of Faculty and TA Development conducted a mid-quarter interview with the AE 625 class in the instructor's absence to identify areas of concern and to propose appropriate changes. Also, a committee of student volunteers met with the AE 625 instructor to communicate how the class was progressing from a student perspective. Prior to the meeting, the committee collected information from the rest of the class through informal conversation and forums.

Preliminary results, recommendations and reflections.

Results.

AE 625. Active learning was achieved through use of portfolios, in-class problem solving, discussions, and student presentations. However, the traditional lecture method was also used when the instructor perceived a need to efficiently cover content material. Students liked the philosophy behind the portfolio method and were willing to engage the instructor by asking questions, pointing out inconsistencies, and making constructive suggestions. The progressive four-level competency matrix enabled students to think about and evaluate their learning and the role of higher order cognition. The self assessment narrative and course evaluation questionnaire prompted further evaluation of the material learned and the learning process itself.

In the previous quarter, the instructor observed senior capstone design project presentations made by current AE 625 students. In comparing these students' presentations to the AE 625 presentations, oral communication skills had improved. This was especially apparent in those students who did not have strong presentations the previous quarter. In addition, the creativity and initiative exhibited in the choice and performance of these application presentations was impressive. Several students arranged plant tours of local industries that employed bioengineering principles, including a large-scale poultry composting facility, a municipal wastewater treatment plant, a high fructose corn syrup manufacturing facility, and a brewery. The students shared slides and information compiled by talking to industrial personnel, thereby enriching the educational process for the rest of the students, and reinforcing theoretical concepts presented in class.

Some students wanted more structure, more definite deadlines, and more directed requirements (i.e., they were uncomfortable with directing and evaluating their own learning progress). Thus far, no learner has attempted other problems or projects not explicitly listed in the syllabus or problem set options list; all students turned in a subset of the instructor defined problems sets. In some cases, student procrastination became a problem. Compounding this, the instructor became a bottleneck as papers to be graded and regraded were submitted at a faster rate than the instructor returned them. This was problem for students trying to complete the course earlier in the quarter. A grader or teaching assistant could alleviate this problem.

BE 1252. The primary reason for implementing portfolios was to encourage active learning strategies and to promote cognition at the higher levels of learning. Active learning has been achieved thus far. This finding is based on the amount of class time spent on active learning strategies, feedback from the students, and assessment of the instructor. Cognition at higher levels of learning has also been achieved based on content of student portfolios, performance on exams that stressed creative solutions to problems, and on originality shown in design projects.

The instructor and students felt that active learning strategies made the course more interesting. Most students reported that the "real world" design project motivated them more than any other aspect of the course. By culminating the design project with an oral and written proposal, students felt that they were working toward a tangible, fulfilling goal. Students appeared to enjoy the portfolio method and the non-traditional approach to this course. While some students complained about the time it took to document their thoughts and progress, none thought that the amount of time they devoted to study outside of class was unreasonable.

The midsemester portfolio check was useful because it illustrated that students had different levels of comprehension concerning the spirit of this project. Those who turned in outstanding portfolios knew they were on the right track, and less prepared students were able to get on track while still enrolled in the course. One check was sufficient for this purpose. The instructor was frequently behind in grading assignments; while a less meticulous grading scheme would have resulted in more expedient return of assignments, the time taken to respond individually to students was worth the increased grading time.

Recommendations and reflections.

AE 625. The portfolio method and the end of quarter evaluation moved the emphasis away from grades, and toward learning and doing the work well. The students reported a lack of stress regarding the course and a sense of freedom in their ability to attempt a variety of design projects and bioengineering application presentations based on their own interests and career goals. Although the point was made regarding the progressive, lifelong nature of learning, the students still treated the matrix in a binary way (i.e., level three and four checks were the only ones that "counted").

By having the instructor define the competency element(s) covered in each homework problem, midterm question, and other items, some of the self-assessment content was lost in terms of having the students make their own evaluation of what competency was being demonstrated. Clarification was needed in some cases, but not all. Perhaps an intermediate stance should be taken next time the course is offered, such as defining the first half of the elements and allowing students to define the second half. The instructor did not enforce the requirement of biweekly progress reports and portfolio checks, but should have, to reduce the problem of procrastination that some students experienced. It is strongly recommended that a grader or teaching assistant be employed to make this approach more feasible, especially for larger class enrollments.

BE 1252. I felt that the portfolio method was an excellent way to engage students. Because the assignments were geared toward students' thoughts and opinions, and discussion was a key element for in-class instruction, the students were increasingly likely to speak out in class. Although this was one of my goals, the experience was disconcerting initially for two reasons. First, I was aware that the more time we spent on discussion in class, the less material we covered. Second, because students were teaching and learning from each other, I didn't feel like I was facilitating "correctly" (by taking up the entire class time lecturing). Although traditional paradigms regarding teaching have merit, I found that students benefited from these new methods. They met my willingness to hear their thoughts and suggestions with their own motivation to improve the course. It was my experience that students given more freedom concerning their learning responded by making challenging choices, generating novel ideas, and being more motivated. My rule of thumb has evolved as follows: if it's something that the class can do and the instructor can facilitate, let the class do it. I used this method to negotiate the grading policy, to present and illustrate concepts, to choose criteria for designating groups for the tiger habitat design, and to choose a method for disseminating their final design for critique.

Although it is not possible to cover as much material using non-traditional means, if the instructor presents situations in such a way that students need to master information that would have been covered in lecture, the students will study and assimilate it on their own. It's more work for the instructor to create such projects, but the payoff is that students see directly how what they are learning is applied in actuality. What an instructor may "lose" in lecture time is made up for by students learning and using that information outside of class time to achieve the goals that instructor and students negotiate together. In addition, students are refining their communication and synthesis skills in the process. Portfolios are a powerful tool for guiding and documenting this endeavor.

References.

Bloom, B.S., Ed. 1953. Taxonomy of educational objectives, handbook I: Cognitive domain. Longmans, Green, New York, NY.

Camp, R. 1990. Thinking together about portfolios. The Quarterly, 12(2): 8-14.

Cress, D. and McCullough Cress, B. 1995. Reflective Assessment: Portfolios in Engineering Courses. http://fairway.ecn.purdue.edu/asee/fie95/4c1/4c14/4c14.htm

Langford, D.P. and B.A. Cleary. 1995. Orchestrating Learning with Quality. ASQC Quality Press, Milwaukee, Wisc.

McClelland, K. 1991. Portfolios: Solution to a problem. In Portfolios: Process and Product. P. Belanoff and M. Dickson, Eds. Boynton/Cook Publishers, Portsmouth, NH. pp. 165-173.

Newcomb, L.H. and Trefz, M.K. 1987. Toward teaching at higher levels of cognition. NACTA J. 31(2): 26-30.

Biographical Information.

ANN D. CHRISTY received her B.S. in Agricultural Engineering and M.S. in Biomedical Engineering both from The Ohio State University, and her Ph.D. in Environmental Systems Engineering from Clemson University in 1991. She is a P.E. and worked in environmental consulting for four years before becoming an Assistant Professor in Food, Agricultural and Biological Engineering at The Ohio State University in 1996.

MARYBETH LIMA received her B.S. in Agricultural Engineering from The Ohio State University, and her Ph.D. in Food, Agricultural and Biological Engineering from The Ohio State University in 1996. She joined the faculty at Louisiana State University as an Assistant Professor in Biological and Agricultural Engineering in 1996.

Figure 1: Competency Matrix

Topic	Competency	Level of learning				
		#1	#2	#3	#4	Portfolio
		Information	Knowledge	Appl/Anal	Wisdom	Reference
Basics	Principles of biology					
	microbiology					
	biochemistry					
Enzymes	Michaelis-Menten model					
	Kinetic reaction rates					
	Effects of inhibitors, etc.					
	Diffusion effects					
Cells	How cells function					
	Metabolism					
	Respiration					
	Material balance					
	Energy balance					
Bioprocesses	Batch growth: models & design					
	CFSTR: models & design					
	Scale-up issues					
	System controls					
	Sterilization					
	Bioseparation & unit ops					
Plants	Photosynthesis					
	Bioregulation models					
Animals	Physiology and growth models					
Ecosystems	Foodchain system models					
Application	Food					
	Agricultural					
	Environmental					
Other skills						