Workbook strategy in engineering education

Yaşar Demirel

Virginia Polytechnic Institute and State University
Blacksburg, United States of America

ABSTRACT: Mismatches between the learning and teaching styles are common because the majority of students are visual and sensing learners, yet most instructors are intuitive and reflective learners. Beside that, textbooks also have their own styles, and their contents, depth of coverage of materials and organisation may affect the teaching and learning. In order to reduce mismatches and achieve effective teaching and active learning, a *workbook strategy* is presented here, which integrates the following four elements: classroom analysis; the use of a workbook beside the textbook; group work; and the use of *blackboard* information technology. The workbook strategy provides all the essential verbal and visual learning elements of the course material in an organised manner, and relates the fundamentals to applications. Therefore, it makes the content of a textbook more extractable and visible, and leads to deeper understanding and problem-based learning. Most students who are exposed to the workbook strategy have found it to be very effective in their learning.

INTRODUCTION

All educational institutions emphasise the importance of effective learning and teaching strategies [1-4]. Society expects that graduates of a modern college would be analytical, intellectually curious, culturally aware, employable and capable of leadership. A student's native ability, background and the match between the learning and teaching styles determine the level of learning. Textbooks also have their own styles, which may affect the learning and teaching processes. Since learning styles are characteristics, instructors should improve the effectiveness of their teaching [5-10].

This study presents the workbook strategy towards effective teaching and active learning implemented in the Department of Chemical Engineering at Virginia Polytechnic Institute and State University, Blacksburg, USA.

WHY THE WORKBOOK STRATEGY?

Engineering students are encouraged to work with real-process applications, demonstrations and hands-on practices beside theory, equations and words [11][12]. Within a textbook, analysis and applications of a topic may be spread out over many pages containing mainly verbal elements of definitions, theory and analysis; relating these elements and applications to each other may be hard or else requires back and forth searches by the user, as seen in Figure 1.

Some educational practices teach students to solve problems using *cookbook* procedures, rather than teaching them how to solve them using engineering analyses. In some institutions, both instructors and students believe that there is no urgent need to change current practices, mainly because of misleading assessments [13][14]. Further, students mainly lack skills in transferring and synthesising knowledge in higher order within a course or across courses [11][15]. On the other hand, the majority of instructors are intuitive learners, while most students are visual and sensing learners [7-9]. Textbooks provide theory and applications in their own styles too. These possible mismatches may adversely affect the teaching and learning processes.

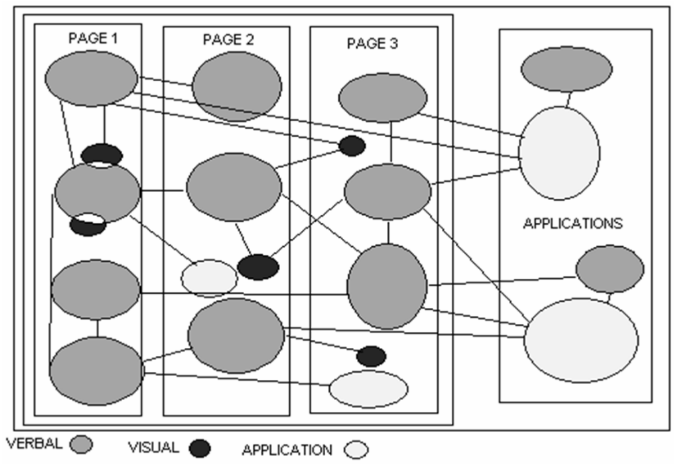

Figure 1: Typical organisation in a textbook, which is rich in verbals and has fundamentals, visuals and applications spread out over several pages.

For example, sometimes students have to search hard to reach a critical analysis in some textbooks. Figure 2 shows how students may communicate with the instructor only, or with the textbook only, while few of them do both in their learning. The instructor may be teaching in a style different from the learning prefer-ences of most students. Since students' learning styles and native backgrounds are characteristics, instructors should improve the effectiveness of their teaching. The workbook strategy may be an effective teaching and learning tool to create critical interactions between students, the instructor and textbook.

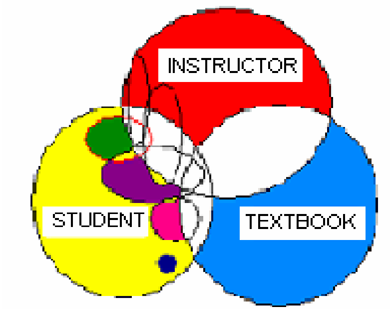

Figure 2: Interactions between the instructor, textbooks and students. Some students interact with the instructor only, some with the textbook only, while some do both. Sometimes the instructor teaches students with certain learning styles only.

LEARNING AND TEACHING PREFERENCES

Preferences in various learning styles may vary among students depending on their field, native ability and background. Learning styles involve verbal or visual input modality, sensing or intuitive perception, active or reflective processing, and sequential or global understanding of course material. On the other hand, teaching styles involve instructor's emphasis on factual or theoretical information, visual or verbal presentation mode, active or reflective student participation, and sequential or global perspective [5]. However, the dimensions of learning and teaching styles are neither unique nor comprehensive [7-10]. For example, a student may have balanced preferences in verbal and visual learning, or one of these may be mildly or strongly preferable. Therefore, a multi-style approach is an essential part of a strategy for an active, collaborative and student-centred learning environment [5][16-21]. An effective teaching technique should engage students actively and stimulate enquiry.

THE WORKBOOK STRATEGY

The workbook strategy integrates the following four elements: analysis of the classroom; use of a workbook beside the textbook; group work; and the use of the *blackboard* information technology aided tool. This may enhance the effectiveness of the instructor and textbook by making the course material more visible and easily extractable, relevant with applications, and reduce mismatches between learning and teaching styles. The following sections describe the elements and implementations of the strategy.

ANALYSIS OF THE CLASSROOM

A classroom analysis reveals: learning preferences (Figure 3), course loads, computational skills, native backgrounds, and specific concerns, such as employment responsibilities, learning disabilities or student athletes. The development of a standard classroom analysis procedure is in progress. This analysis can help the instructor to communicate with the classroom more effectively, and establish groups consisting of students with different learning preferences so that they may teach each other in their group work. The Felder-Soloman's Index of Learning Styles (ILS) is a statistically acceptable tool for assessing the learning preferences of engineering students [9][22][23]. The ISL has been used to assess the learning preferences of 36 students taking a separation course; the index shows that 85% of the students have a mild to strong preferences for visual learning, while about half of them are active learners [24].

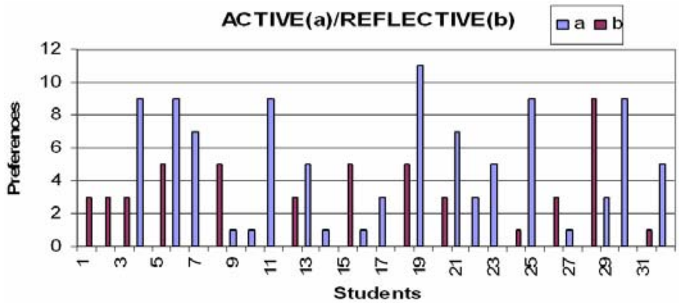

Figure 3: Learning preferences within the active/reflective learning styles for the students in the separation course.

THE WORKBOOK

The workbook presents the course material with all the essential verbal and visual learning elements taken from the textbook in a systematic and organised way to teach students with various learning preferences and diverse backgrounds. The visual elements are most of the related simulation or experimental presentations, graphs, diagrams, flow charts, tables, pictures, figures and data. The verbal elements include theory and analysis, definitions and equations. Within the workbook, visual and verbal elements support each other in a categorised way so as to relate fundamentals to applications as a package (see Figure 4). Consequently, this may reduce mismatches between learning and teaching styles and leads to an effective teaching strategy.

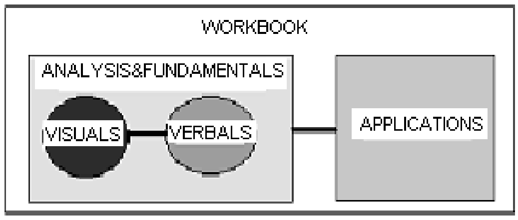

Figure 4: Ideal organisation of a workbook page, which has visual and verbal elements supporting each other and relates fundamentals to applications.

However, some of the verbal and visual learning elements are deliberately left incomplete or missing. The instructor delivers the lectures from the transparencies of the workbook with an overhead projector, and completes the missing verbals and visuals jointly with students. Note-taking becomes systematic and organised, and requires less time, since the crucial diagrams, figures and some fundamentals are already provided. The time saved for having a figure or a chart in the right time and location can be channelled to critical thinking, asking questions, and in-class group work. The workbook identifies examples, practice and homework problems and allocates spaces for them, and encourages problem-based learning. Students and the instructor discuss these problems to relate fundamentals to applications. The best format of a workbook mainly depends on the instructor's experience, the textbook's organisation, the level of the course, and student feedback.

The workbook strategy has been implemented in three engineering courses [24-26]. The first workbook is 108 pages, prepared for the textbook, *Introduction to Chemical Engineering Thermodynamics*, by Smith et al [27]. The second is 97 pages, prepared for the simulation course using the textbook, *Numerical Methods for Engineers*, by Chapra and Canale [28]. The last one has 118 pages, prepared for the textbook, *Equilibrium Staged Separation*, by Wankat [29]. A typical page format from the thermodynamic workbook is shown in Figure 5, which starts with the concept of power generation. Next, the cyclic process and the efficiency of a heat engine are described. In the following box, the Carnot efficiency and theorem are discussed. The concept of reversibility is associated with the Carnot engine. Later, the power generation is elaborated starting with the pump as the starting stage of cyclic operation; next the boiler and the supply of heat is discussed; turbine operation and production of work in the form of electricity is emphasised; finally, the condenser and related cooling towers are discussed. Within the bottom box, the instructor and students solve an example problem jointly. Thus, students are exposed to analysis and application in a compact manner.

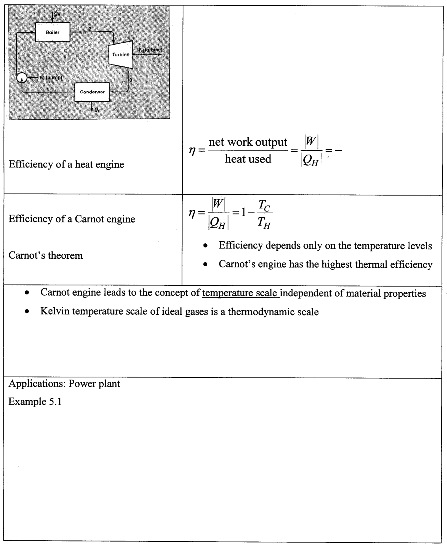

Figure 5: A typical workbook page from a thermodynamics course, describing heat engines and power generation.

Figure 6 shows a typical page from the workbook prepared for the simulation course. Here, the straight line fit to data is discussed with three graphs. The least-square fit of a straight line is analysed by expressing the slope and intercept of a_1 and a_o, respectively; they are calculated within the example 17.1 using the tabulated x and y values. Later, the coefficient of correlation is explained and calculated for the same example to assess the quality of fit.

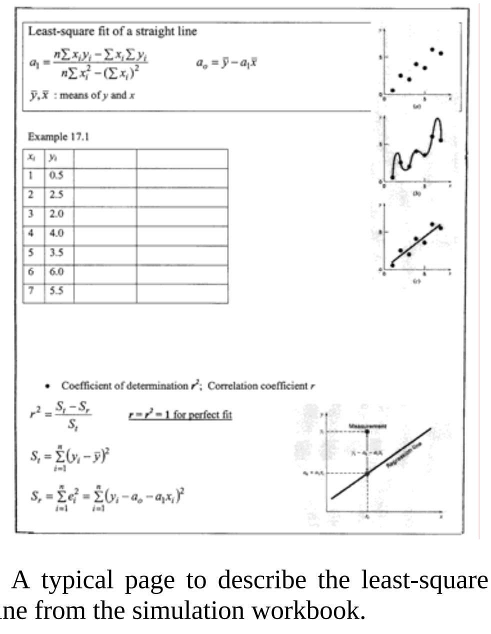

Figure 6: A typical page to describe the least-square fit of a straight-line from the simulation workbook.

Figure 7 shows a completed page from the separation course. It presents an application of theory introduced previously in the vapour-liquid equilibrium calculations. Here, bubble point and dew point temperature calculations are described, and known and unknown variables are identified. The flow chart indicates the iteration steps. Underneath, the analysis is presented in a step-by-step fashion, and compared for the two types of calculations. A group work was assigned for a ternary mixture bubble point and dew point calculations. In some textbooks, this analysis is related to applications over several pages and requires back and forth search by the user.

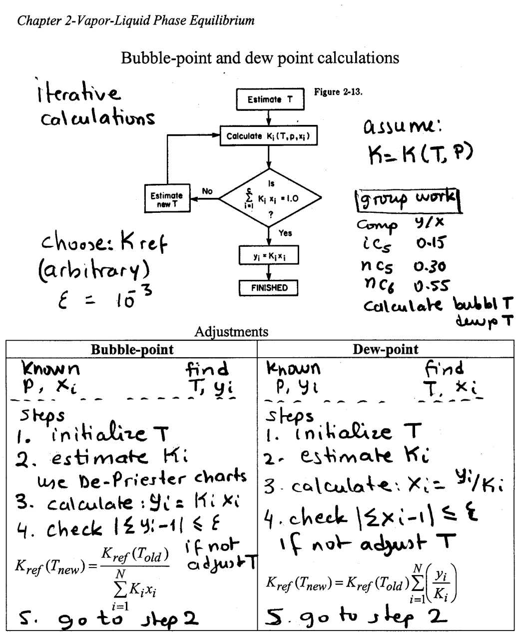

Figure 7: A typical completed workbook-page for separation processes course for bubble and dew point temperature calculations and group work [26].

GROUP WORK

In this example, groups consist of two or three students with different learning preferences. Group work activity consists of in-class group work, and out-class group work.

For in-class group work, the instructor prepared and distributed group packages, in which groups recorded all their activities throughout the semester. In practically every lecture, groups had to solve a short problem related to freshly introduced fundamentals and analysis. They worked for about 10 to15 minutes and submitted the packages, which were then checked by the instructor and returned.

Group work promotes collaborative learning. Around 90% of students agreed and tended to agree that they had learned from each other, and that the group work had been an active-learning tool because of hands-on practice.

BLACKBOARD

Blackboard information technology is a secure, Web-based educational and communication platform. Instructors can use *blackboard* to provide students with supplemental course materials, assignments, group projects, assignment, solutions, test objectives, announcements and communications via e-mail. Student information systems, such as Datatel Colleague and People Soft SIS, are available in the *blackboard learning systems*.

PRELIMINARY ASSESSMENTS

Using a questionnaire prepared by the author, preliminary assessments have been carried out after 12 weeks with the workbook strategy. Respondents number 47 for the thermodynamics course, 31 for simulation, and 36 for the separation course [24-27]. The questions are treated with the same weight.

Around 90-92% of students agreed and tended to agree that:

- The workbook strategy reduced mismatches between learning and teaching styles, and hence offered a multi-style learning environment for students with various learning preferences;
- Enhanced problem-based learning, subject-specific skills and stimulated active learning;
- Stimulated group work and collaborative learning.

The following are some examples of the written comments by students:

- *I highly approve of the use of workbook. It gives the students time to reflect on what is going on in the class instead of just blindly copying down notes. I encourage all teachers to adopt the workbook, which causes positive interactions between student and teacher.*
- *I really like the workbook. It makes the information a lot more clear, so we can understand the concepts then go back to look at it.*
- *It condenses textbook into more meaningful and useful notes; makes more difficult concepts easier to understand.*
- *It motivates learning, reviewing and comprehension. I wish workbook would be used in all of my classes.*

REFERENCES

1. National Research Council, From Analysis to Action. Undergraduate Education in Science, Mathematics, Engineering, and Technology. Washington, DC: National Academy Press (1996).
2. McCowan, J.D., An integrated and comprehensive approach to engineering curricula, part two: techniques. *Inter. J. of Engng. Educ*., **18**, 638 (2002).
3. Streveler, R.A., Moskal, B.M., Miller, R.L. and Pavelich, M.J., Center for Engineering Education: Colorado School of Mines. *J. of Engng. Educ*., **90**, 381 (2001).
4. Stice, J.E., Felder, R.M., Woods, D.R. and Rugarcia, A., The future of engineering education IV: learning how to teach. *Chemical Engng. Educ*., **34**, 118 (2000).
5. Felder, R.M. and Brent, R., *Effective Teaching: A Workshop*. Winona, USA (2001).
6. Felder, R.M., Felder, G.N. and Dietz, E.J., The effects of personality type on engineering student performance and attitudes. *J. of Engng. Educ*., **91**, 3 (2002).
7. Felder, R.M., Reaching the second tier: learning and teaching styles in college science education. *J. Coll. Science Teaching*, **23**, 286 (1993).
8. Felder, R.M. and Silverman, L.K., Learning and teaching styles in engineering education. *Engng. Educ*., **78**, 674 (1988).
9. Felder, R.M. and Soloman, B.A., Index of Learning Styles Questionnaire, North Carolina State University (2001), http://polaris.umuc.edu/~rouellet/learning/felder.htm
10. Zywno, M.S., Engineering instructor teaching styles and attitudes toward student-centered and teaching-enabled teaching strategies. *Proc. ASEE Annual Conf. and Expo.*, Nashville, USA, Session 1122 (2003).
11. Ellis, G.W., Mikic, B. and Rudnitsky, A.N., Getting the "big picture" in engineering: using narratives and conceptual maps. *Proc. ASEE Annual Conf. and Expo*., Nashville, USA, Session 2531 (2003)
12. Fogler, H.S. and Leblanc, S.E., *Strategies for Creative Problem-Solving.* Engelwoods Cliffs: Prentice Hall (1994).
13. Elger, D., Beller, J., Beyerlein, S. and Williams, B., Performance criteria for quality in problem solving. *Proc. ASEE Annual Conf. and Expo*., Nashville, USA Session 2230 (2003).
14. Zywno, M.S., A contribution to the validation of score meaning for Felder-Soloman's Index of Learning Styles. *Proc. ASEE Annual Conf. and Expo.*, Nashville, USA, Session 2351 (2003).
15. Schneck, D.J. Integrated learning: paradigm for a unified approach. *J. Engng. Educ*., **90**, 213, (2001).
16. Felder, R.M., How to survive engineering school. *Chemical Engng. Educ*., **36**, 30 (2002).
17. Recommendations for Action in Support of Undergraduate Science, Technology, Engineering and Mathematics, Project Kaleidoscope Report on Reports (2002), http:/www.pkal.org/template2.cfm?c_id=387
18. Bean, J.C., *Engaging Idea: The Professor's Guide to Integrating Writing, Critical Thinking, and Active Learning in the Classroom*. San Francisco: Jossey-Bass Publishers (2001).
19. Buch, N.J. and Wolf, T.F., Classroom teaching through inquiry. *J. Professional Issues in Engng. Educ. Practice*, **126**, 105 (2000).
20. Felder, R.M. and Brent, R., Effective strategies for cooperative learning. *J. Coopertive Collaborative Coll. Teach*., **10**, 63 (2001).
21. Fitch, B. and Kirby, A., Students' assumptions and professors' presumptions: creating a learning community for the whole student. *Coll. Teach*., **48**, 47 (2000).
22. Livesay, G., Dee, K., Felder, R.M., Hites, I., Nauman, E. and O'Neal, E., Statistical evaluation of the index of learning styles. *Proc. ASEE Annual Conf. and Expo.*, Montreal, Canada, Session 2430 (2002).
23. Van Zwanenberg, N., Wilkinson, L.J. and Anderson, A., Felder and Silverman's index of learning styles and Honey and Mumford's learning styles questionnaire: How do they compare and do they predict academic performance? *Educ. Psychology*, **20**, 365 (2000).
24. Demirel, Y., Effective teaching and active learning of engineering courses with workbook strategy. *Proc. ASEE Annual Conf. and Expo.*, Salt Lake, USA, Session 3213 (2004).
25. Demirel, Y., Teaching engineering courses with workbooks. *Chem. Engng. Educ*., **38**, 74 (2004).
26. Demirel, Y., Teaching chemical engineering courses with workbook strategy. *Proc. ASEE Southeastern Section Meeting*, Auburn, USA (2004).
27. Smith, J.M., Van Ness, H.C. and Abbott, M.M., Introduction to Chemical Engineering Thermodynamics, Sixth Ed., McGraw-Hill, Boston (2001).
28. Chapra, S.C. and Canale, R.P., *Numerical Methods for Engineers* (4th edn). Boston: McGraw-Hill (2002).
29. Wankat, P.C., *Equilibrium Staged Separations*. Englewood Cliffs: Prentice Hall (1988).