Workbook strategy in engineering education

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ABSTRACT: Mismatches between the learning and teaching styles are common because students are in majority 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 organization may affect the teaching and learning. For reducing the mismatches, and achieving effective teaching and active learning, we present “workbook strategy,” which integrates the following four elements: (i) classroom analysis, (ii) use of workbook beside textbook, (iii) group work, and (iv) use of ‘blackboard’ as information technology. The workbook strategy provides all the essential verbal and visual learning elements of the course material in an organized way, and relates the fundamentals to applications. Therefore it makes the content of a textbook more extractable and visible, and leads to deep understanding and problem-based learning. Most of the students who are exposed to the workbook strategy have found it very effective in their learning.

INTRODUCTION

All educational institutions emphasize the importance of effective learning and teaching strategies [1-4]; society expects that graduate of a modern college would be analytical, intellectually curious, culturally aware, employable, and capable of leadership. 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 the learning styles are characteristics, instructors should improve the effectiveness of their teaching [5-10].

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

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; to relate these elements and applications to each other may be hard or requires back and forth searches by the user, as seen in Figure 1.

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

Some educational practices teach students to solve problems using cook-book procedures rather than teaching how to solve them in engineering analysis. In some institutions, both instructors and students believe that there is no urgent need for changing the current practices, mainly because of misleading assessments [13-14]. Beside that, students mainly lack the skill of transferring and synthesizing knowledge in higher order within a course or across courses [11,15]. On the other hand, most instructors are intuitive learners, and students are in majority visual and sensing learners [7-9]; textbooks provide theory and applications in their own styles too. These possible mismatches may affect the teaching and learning processes adversely. For example, sometimes, students have to search hard to reach a critical analysis in some textbooks; as Figure 2 shows that, some students may communicate with instructor only, or with textbook only, and few of them with the both in their learning; instructor may be teaching in a style different from the learning preferences of the majority of students. Since the student’s learning styles and native background are characteristics, instructors should improve the effectiveness of their teaching. The workbook strategy may be effective teaching and learning tool by creating critical interactions among students, instructor, and textbook. The strategy is elaborated within the next section.

Figure 2. Interactions among instructor, textbook, and students. Some students would interact with instructor only, some with textbook only, and some with the both. Sometime instructor teaches students with certain learning styles only.
LEARNING AND TEACHING PREFERENCES

Preferences in various learning styles may vary among students depending on the field, the native ability, and the background. Learning styles involve verbal or visual input modality, sensing or intuitive perception, active or reflective processing, and sequential or global understanding of a 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-centered learning environment [5,16-21]. An effective teaching technique should engage students actively, stimulate sense of enquiry.

THE WORKBOOK STRATEGY

The workbook strategy integrates the following four elements: (1) analysis of classroom, (2) use of workbook beside textbook, (3) group work, and (4) use of ‘blackboard’ as information technology aided tool. It may enhance the effectiveness of instructor and textbook by making the course material more visible and easily extractable, relevant with applications, and reduce the mismatches between the learning and teaching styles. The following sections describe the elements and implementations of the strategy.

ANALYSIS OF CLASSROOM

Classroom analysis reveals: (i) learning preferences (Figure 1), (ii) course loads, (iii) computation skills, (iv) native background, and (v) specific concerns, such as employment responsibilities, or learning disabilities, or student athletes. 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 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) [9] is a statistically acceptable tool for assessing the learning preferences of engineering students [22,23]. The ISL has been used to assess the learning preferences of 36 students taking the separation course; the index shows that 85 % of the students have a mild to strong preferences for visual learning, and 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 organized 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. While the verbal elements include theory and analysis, definitions, and equations. Within the workbook, visual and verbal elements support each other in a categorized way to relate fundamentals to applications as a package as seen in Figure 4. Consequently, this may reduce mismatches between the learning and teaching styles and leads to effective teaching strategy.

![WORKBOOK]

Figure 4. Ideal organization 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. Instructor delivers the lectures from the transparencies of the workbook with an overhead projector, and completes the missing verbs and visuals jointly with the students. Note taking becomes systematic and organized, 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 channeled to critical thinking, asking questions, and in-class group work. The workbook identifies example, practice, and homework problems and allocates spaces for them, and encourages problem-based learning. Students and 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 organization, the level of the course, and feedback from the students.

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 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 boiler and the supply of heat is discussed; turbine operation and production of work in the form of electricity is emphasized; finally, condenser and related cooling towers are discussed. Within the bottom box, instructor and the students solve an example problem jointly. Therefore, the students are exposed to analysis and application in a compact way.

Figure 5. A typical workbook page from the thermodynamics course to describe the 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 a data is discussed with the three graphs. The least-square fit of a straight line is analyzed by expressing the slope and the intercept of \( a_1 \) and \( a_0 \), respectively; they are calculated within the example 17.1 using the tabulated \( x \) and \( y \) values. Later, coefficient of correlation is explained, and calculated for the same example to assess the quality of the 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 on the vapor-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 step-by-step, 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

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, instructor prepares and distributes group packages, in which groups record all their activities throughout the semester. Practically in every lecture, groups solve a short problem related to freshly introduced fundamentals and analysis. They work about 10 to 15 minutes, and submit the packages, which are checked by the instructor and returned in. Group work promotes collaborative learning. Around 90% of the students agree and tend to agree that they have learned from each other, and the group work has been an active-learning tool because of hands-on practices.

‘BLACKBOARD’

“Blackboard” information technology is a secure, Web-based educational and communication platform. Instructor can use ‘blackboard’ for providing students with supplemental course material, assignments, group projects, assignment, solutions, test objectives, announcements, and communications with email. Student information systems, such as Datatel Colleague, 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. For the thermodynamics 47, for the simulation 31, and 36 students for the separation course have responded [24-27]. The questions are treated with the same weight. Around 90 -92% of the students agree and tend to agree that workbook strategy: (1) reduces mismatches between the learning and teaching styles, and hence offers a multi-style learning environment for the students with various learning preferences, (2) enhances problem-based learning, subject-specific skills, and stimulates active learning, and (3) stimulates group work and collaborative learning. The following are some examples of the written comments by the 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

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