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Student Evaluation of Instructional Modules on EC 2000 Criteria 3 (a) – (k) Skills

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Abstract

A team of engineering faculty members has developed a set of fifteen instructional modules for teaching several skills identified in EC 2000 Criteria 3 (a)-(k). Module developers designed them for a week of classes in upper-level engineering courses and incorporated active/cooperative learning and web-based resources. In addition to the standard instructional material, each module contained learning objectives, a justification, student exercises and assignments, and an instructor's guide discussing the use of the material and the grading of student work. To determine students' reaction to these modules, we had instructors, who were not the module developers, teach them to a class of engineering students. The students completed extensive evaluation forms, including a series of questions where they indicated their agreement with a set of positively oriented statements on the material using a five-point scale (1 – *"Strongly Disagree"* to 5 – *"Strongly Agree").* These data indicated a positive student reaction to the instructional material. For example, the overall average scores on the statements about the learning objectives, justification, teaming activities, and homework were 4.1, 4.2, 3.9, and 3.9, respectively. The two modules with the highest overall average scores dealt with ethics (4.4) and oral communications (4.4); the two with the lowest overall average scores dealt with lifelong learning (3.6) and contemporary issues (3.7).

Introduction

The EC2000 guidelines require that engineering programs to demonstrate that their graduates have acquired a set of specified skills, including design, experimental, problem solving, teaming, communication, lifelong learning, ethical interpretation, and global and societal impact skills [1]. To date most of the creative work has focused on the assessment aspects -- establishing goals, objectives, and outcomes, identifying assessment tools, and defining feedback mechanisms. In contrast, the development of classroom material for newly emphasized skills and technology related knowledge, as defined in Criteria 3, Items (a) through (k), has received considerably less attention. Traditionally, engineering courses have focused on technical content and presumed that students developed these other skills, sometimes called "processing skills", by working with the technical content and by observing the instructor working with it in the classroom. Educational research, along with many anecdotal reports from industry, indicates the ineffectiveness of this ad hoc approach [2, 3]. Because EC2000 requires an assessment process that demonstrates acquisition of these processing skills, engineering programs must ensure that their curriculum includes instruction and practice in these skills.

Since most engineering curricula do not have room for additional courses on processing skills, programs must add components on specific skills to existing courses. Further support for this approach comes from educational research that indicates that students learn processing skills much better when they are taught in a technical context as a part of a standard engineering course than when they are taught in stand-alone courses [3, 4]. Since most engineering faculty members have little or no experience in teaching processing skills, efficient and effective instruction in these skills will require well-designed instructional material that is not widely available at the present time. These new instructional modules should include classroom material, student assignments and, most importantly, a guide for instructors.

Module Development and Specification

A group of ten faculty members worked over two years to develop a set of fifteen instructional modules that deal with a set of skills derived from Criteria 3 (a) - (k) in the EC 2000 Guidelines[1]. The skills were grouped into four categories as shown in Table 1.

Technical Skills	***Professional Skills***	***Communication Skills***	***Ethical-Societal Skills***
Computational	Project Management	Graphical Communication	Contemporary Issues
Design	Lifelong Learning	Oral Communication	Ethical Interpretation
Experimental	Teaming	Written Communication	Global-Societal Impact
Modeling	Time Management		
Problem Solving			

Table 1. *Instructional modules subdivided by skill category*

Before beginning to develop the actual instructional material, the developers agreed on a set of specification so that the modules met a series of general requirements and, perhaps equally important, had a similar look. We decided that the modules should:

- Fit into one week of classes (three 50-minute sessions)
- Serve all engineering curricula
- Utilize standard classroom facilities unless special facilities were part of the skill
- Require a small amount of preparation time by the instructor
- Fit into engineering courses above the freshman level
- Use active/cooperative learning
- Utilize web resources when possible and appropriate

We also decided that the module material should contain:

- Clear measurable learning objectives
- A clear justification that shows how the skill meets a perceived student need
- Multiple student exercises
- Assignments that bridge the skill into the discipline
- An instructor's guide discussing the use of the material

The fifteen modules are available on the web site at ece.ua.edu/faculty/rpimmel/public_html/ec2000-modules. In the following discussion, we will

cite examples from the five modules that the three authors of this paper developed. These modules deal with computational, oral communication, project management, ethical interpretation, and global and societal impact skills.

Module Description

In most of the modules, the material alternated short mini-lectures describing some established ideas with cooperative learning exercises with students reporting to the entire class as a part of the exercise. This approach provided some instruction in the skill, followed by a chance to practice it, followed by a chance to see and evaluate other student's efforts and to have their work evaluated both by students and the instructor -- all important steps in learning a skill [2, 3].

Restricting the modules to three 50-minute classes forced us to select a subset of material. For example, the global and societal impact module was designed to heighten students' awareness of the impact of the solutions which they, as engineers, will design and implement in their careers. The material emphasized key responsibilities, including the responsibility to anticipate consequences of their actions, to inform society of the impact of their proposed solutions, and to ensure that society gives input and approval before a solution is implemented. It outlined procedures to ensure that engineers exercise these responsibilities, and it had the students analyze case studies using these procedures and present the result of their analysis to the class.

In the more technical modules, the time constraints forced similar choices. In the project management module, the first session used mini-lectures and group-exercises to define a project and the role of projects and project management in modern industry. The second and third sessions introduced several project management tools (i. e., work breakdown structures, linear responsibility charts, activity networks, and the Gantt charts) and provided in-class exercises where students applied these tools in developing project-planning documents.

The computational skill module used Mat lab as a tool in developing some of the basics strategies in computational approaches. The goals of the three sessions were to prepare the students to determine the accuracy of computed results, to give a step-by-step description of how to compute the solution to an engineering problem, and to use Mat lab to solve certain computational problems.

Team Exercise: Team exercises, which took many forms, were an important part of the instructional activities. For example, the first session of the oral communication module contains two team exercises, each taking about ten minutes of class time. The first asked the students to prepare a set of guidelines for effective presentation while the second ask for a set of PowerPoint slides. These team exercises actively involved the students and got them thinking about the characteristics of good presentations and slides, thereby making them more receptive to the material presented by the instructor. Announcing ahead of time that a few randomly selected teams had to report their results encouraged all students to take these exercises seriously. Also, the material includes a brief discussion of teaming strategies just before the first team exercise in order to remind the students of some of principles of good teaming.
In the global and societal impact module, group activities involved developing various steps in the process used to evaluate the impact. For example, in the first session, groups were asked to

provide three real-world examples of proposed engineering solutions which have had a significant impact on society, to briefly discuss the original problem which inspired each proposed solution, and to determine the positive and negative impacts of each of the solutions. In the second session, they were asked to identify resources to help them find problems similar to the one they were considering, to identify technological trends associated with the proposed solution, to project possible societal impact of these trends so that unintended consequences can be anticipated, and to research any laws or regulations which may exist concerning a proposed solution.

Homework Assignments: The oral communication module, like many of the others, contained two types of homework assignments. The first type were simple exercises that encouraged the students to think about the importance of good presentation skills and to consider, organize and prioritize the factors that lead to effective presentations. Sample questions were *"List two reasons why engineers need to develop good presentation skills."* and *"Prepare a single list of the five most important guidelines for planning, preparing, and delivering a talk. Write a sentence or two justifying your choices."* The second type of assignment directed the students to web sites or printed material and required them, normally as members of a team, to prepare a short talk on some topic dealing with presentation skills. Topics included common mistakes in delivering a presentation, preparing for questions, preparing for a hostile audience, and dealing with nervousness.

The project management module also used two types of assignments. The first set encouraged the students to think about project management issues, to become familiar with web-based resources on these issues, and to develop some perspective on them. The second set directed students to complete project-planning documents for a project involving a student activity. These assignments provide the students with an opportunity to develop various project-planning documents for non-technical, student activity projects, for example planning for a high school day or a student presentation to an industrial advisory committee. Since these exercises are free of technical details and complexities, students can focus on the planning issues with a minimum of confusion (i. e., develop the skill in a "context-free" environment).

Two assignments were given in the global and societal impact assessment module. At the end of the first session, students were asked to develop a set of specific procedures which practicing engineers can use to ensure that unintended consequences are limited, that society is informed of the tradeoffs involved in an engineering solution, and that society gives approval before the solution is implemented. At the end of the second session, students were asked to prepare a short presentation discussing the positive and negative, intended and unintended consequences of a specific technological development that the instructor selected from a list prepared in an in-class exercise in the first session. The presentations were given in the third session, and the group and audience were asked to "second guess" and discuss what they would have done to anticipate unintended consequences and to "improve" the solutions.

In the computational skills module, a pre-module exercise was assigned to be turned in at the first class, to get the students thinking about the problem. Additional exercises were given to reinforce the skills taught in each class.

Instructor's Guides: The instructor's guide for the module on oral communication skills discusses several aspects that are important in teaching this module in an engineering course. The major sections provide tips on

- Using the instructional material (e.g. PowerPoint slides).
- Homework assignments.
- Grading student work.
- Assessment.

In addition, some of the instructor's guide also provided references to additional resources that the instructor could use, alternate homework assignments, tips for bridging the material into specific disciplines, explanations on why the module was developed the way it was (i.e., motivation of the developer and what he 0r she found to be effective or ineffective).

Grading homework was critical in order to encourage students to take the topic and assignment seriously and make a reasonable effort. Grading this type of homework will be difficult for many engineering instructors because the answers usually are verbal and subjective with no single right answer. Most of the instructor's guides provided tips on grading assignments. In the project management module, the guide suggests that when grading problems that ask for a definition, list, or process, the instructor should grade for responsiveness, reasonableness, completeness, and the use of appropriate references if requested. Thus the grading criteria are:

- Responsive -- Does the answer address the question?
- Reasonable -- Does answer make sense?
- Complete -- Does answer include a complete response to the question?
- Referenced -- Is the web site reference correct and complete?

These criteria basically enable the instructor to determine if the student read the question, visited the web site(s), read the material at the site, thought about it, and constructed an appropriate response.

Grading problems that asked students to perform an analysis or synthesis task, for example, use one of the project management tools (e. g., a work breakdown structure) in planning a project, also requires the use of subjective criteria. The guide suggests that the instructor determine if the submitted work dealt with the assigned project in a reasonable and complete way, if it has the correct format, and if it is presented in an understandable style as summarized in the following checklist:

- Responsive -- Does it deal with the assigned project?
- Reasonable -- Do the details make sense?
- Complete -- Does it include all aspects of the project?
- Correct -- Is the format correct and consistent with class material?
- Neat and Orderly -- Is it readable, well organized, and easily understood?

The instructor may actually give this list to the students when he or she makes the assignment. The key is to get the students to recognize and generate good project planning documents and to give them feedback on how well they did this. Knowing exactly what the instructor expects will encourage the students to follow the guidelines for a good result.

Module Evaluation

Each module was tested in an evaluation program where a faculty member, other than the developer, taught the material to a group of approximately ten students in a classroom setting. Each class was randomly selected, after a pre-selection based on schedule compatibility, from a group of students containing students form most disciplines in engineering with 65 % seniors, 25 % juniors, and 10 % sophomores. In this population, 45 % had a GPA above 3.0 while 55 % had one between 2.0 and 3.0, and 61 % had one or more coop or intern experiences, while 39 % had none. In response to a question about their formal training in the module topic, 48 % indicated that they had no experience, 36 % indicated experience in one or two classes, and 16 % indicated experience in three or more classes.

In a survey conducted after the module, we asked the students to indicate their agreement with a set of statement describing the appropriateness, effectiveness and completeness of the material. For example, we asked them to indicate their agreement with *"The learning objectives were clear"* and *"The instructional material supported the learning objectives."* Figures 1 through 6 (discussed below) contains a complete list of these questions in a slightly abbreviated form. Students responded to each statement using a five valued scale (i. e., 1 -- "*Strongly Disagree*", 2 -- "*Disagree*", 3 -- "*Neutral*", 4 -- "*Agree*", and 5 -- "*Strongly Agree*"). For each statement, we averaged the selected values and we will refer to this average as the "agreement score" with larger values indicating a favorable response and lower scores indicating an unfavorable response. The survey form also provided opportunities for written comments on the appropriateness, effectiveness and completeness of the material. A companion paper describes data from a second survey in which the students evaluated their confidence in their ability to complete tasks derived from the learning objectives before and after the module [5].

Results

Figure 1 shows the average agreement scores for the modules in each of the four categories of skills (i. e., professional, technical, communication, and ethical-societal). In evaluating this data it is helpful to interpret the scores in terms of the effective percentage of students that selected the descriptive terms that enclose the value. For example, an average score of 3.6 indicates that on the average 60 % of the students selected "*Agree*" while 40 % selected "*Neutral*; similarly an average score of 4.2 indicates that effectively 20 % selected "*Strongly Agree*" while 80 % selected "*Agree*". The data show that, pretty much across the board, the students agreed that the objectives were clear and supported by the material and that the justifications were clear and convincing. They also agreed, but to a slightly lesser extent than the in-class activities and the homework assignments were appropriate for modules in all four categories. With the next three questions, the responses were much more mixed with average scores near 4.0 in some cases and near 3.5 in others (again a score of 3.5 implies that effectively one half of the students agreed with the statement and one-half were neutral). The modules on the professional skills fared best with scores near 4.0 on the three statements; while the modules on ethical-societal skills feared worst with scores near 3.5 on these statements.

The agreement scores for the five modules developed by the three authors are shown in Figures 2 through 6. The discussion of these figures will relate the numerical agreement scores to the students' written comments in the following paragraphs as examples of the detailed evaluation of each module.

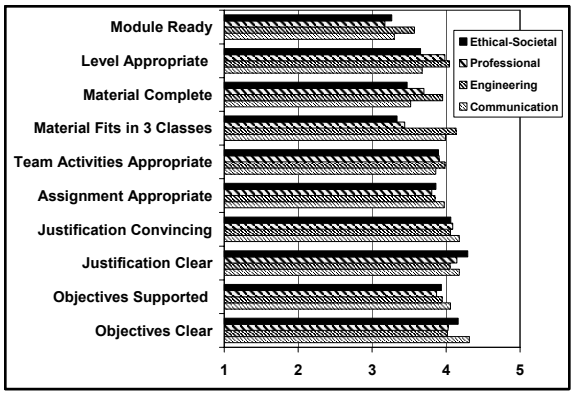

Figure 1. *Average agreement scores for each skill area.*

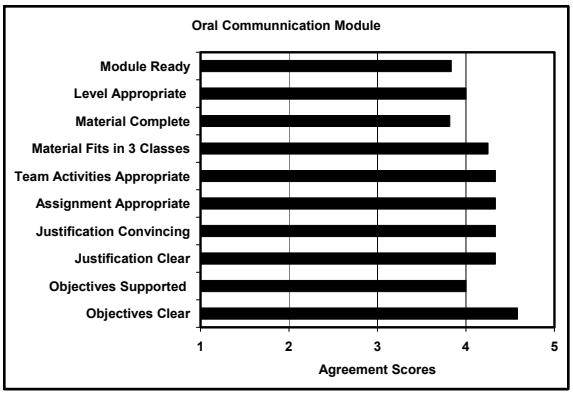

Figure 2*. Agreement scores for the oral communication module*

<u>*Oral Communication Skills Module:*</u> Figure 2 shows the agreement scores for the oral communication module. Most of these scores are near to or greater than 4.0, indicating that the students agreed with the statements and felt that the module's material was clear and appropriate. Aside from the overall judgment statement ("*The module is ready for release.*"), the statement on the completeness of the material had the lowest value (3.5). The written comments addressed three themes. First, there were considerable comments on the repetition in the student presentation -- this occurred because the instructor let student teams pick their topic from the list on the assignment and several chose the same topic. Having the instructor select the topics or having the student teams draw their topics will eliminate this problem and ensures a broader coverage of ideas. The second theme addressed a need for a more advanced discussion (i. e., "the qualities of a good communicator" and "ways to give an effective presentation"). The developer did not change the module because he intended it to be an introductory and not an advanced exposure to presentation skills. Finally, the third theme dealt with a more formal approach for peer evaluation of their presentations. This would be an excellent addition; however, there simply is not enough time to approach peer evaluation in a serious way. However, a simple form could be used in the peer evaluation process and it would add some structure and consistency to the process.

<u>*Computation Skills Module:*</u> Figure 3 shows the agreement scores for the computational skills module. Most of these scores are near to or greater than 4.0. Aside from the overall judgment statement ("*The module is ready for release.*"), the statements on the clearness of the objectives and on the team activities had the lowest values (3.5 and 3.6, respectively). The written comments addressed several issues: (1) several students commented that they had seen most of the material in prior coursework; (2) several students requested more material on error analysis, which was a topic they had not seen before; (3) several students thought that too much material was specific to Mat lab rather than computation in general; and (4) the class represented a wide

diversity of experience with computation, Mat lab, and mathematics. Most of these issues are influenced by where the module is used in the curriculum and can be eliminated by proper placing of the module in the curriculum. The developer revised the instructors guide to clarify how to present the material. The developer chose to continue to use Mat lab exclusively, as it is both easily and widely used, and allows the students to focus on the computation problem, and not on program syntax.

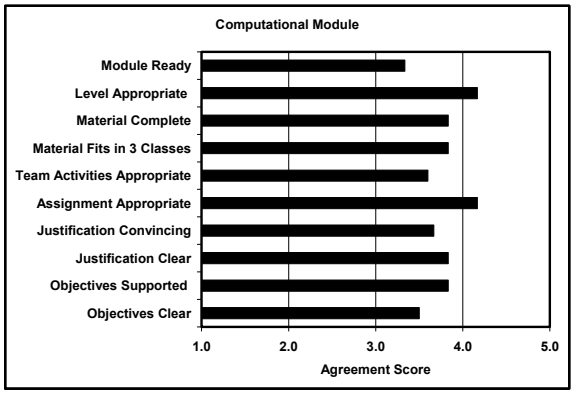

***Figure 3**. Agreement scores for the computational module*

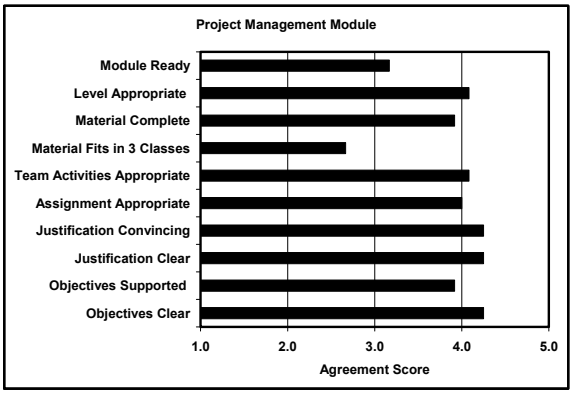

***Figure 4.** Agreement scores for the project management module*

<u>*Project Management Module:*</u> Figure 4 shows the agreement scores for the project management module. With two exceptions, the scores were greater than 4.0, indicating that, for the most part, the students felt that the material was clear and appropriate. The two exceptions were the overall judgment statement ("*The module is ready for release.*") and the statement on the material fitting into three classes with scores of 3.2 and 2.7, respectively. The latter is a particularly low score indicating a major problem with the amount of material. The written comments were very positive about the objectives and the justification. They strongly indicated that there was too much material for three 50-minute sessions, supporting the numerical data. In response to this strong criticism, the developer dropped coverage of some project management tools and shortened a few of the in-class exercises.

<u>*Global and Societal Impact Module:*</u> Fig 5 shows the agreement scores for the global and societal impact module. Scores for the statements on the objectives and the justification were near 4.0, indicating the students agreed that these components were sufficiently handled. Scores for the remaining items, especially appropriateness of assignments and the amount, level, and completeness of the material, were below 4.0 and some near 3.0, indicating that the students felt that this module needed significant revision. Many student comments indicated that the issue of global and societal impact was too large to properly cover in 3 class-hours. The module developer had tried to address this issue by crafting the module not as a survey of engineering solutions and their societal impact, but rather to focus on what engineers could do to assess impact, inform the public and gain their consent, and anticipate unintended consequences. The developer has added a comment in the instructor's guide requesting the instructor to discuss the focus of the module during its introduction to the class. Another issue addressed in student comments was that the example used to illustrate unintended consequences was too weak. (The

developer, having a southern audience, had chosen the introduction of the plant Kudzu to the southern US to fight soil erosion. Kudzu has grown too well and has taken over acres of land, strangling out native trees and vegetation.) A more relevant and universal example will be used in the revised module.

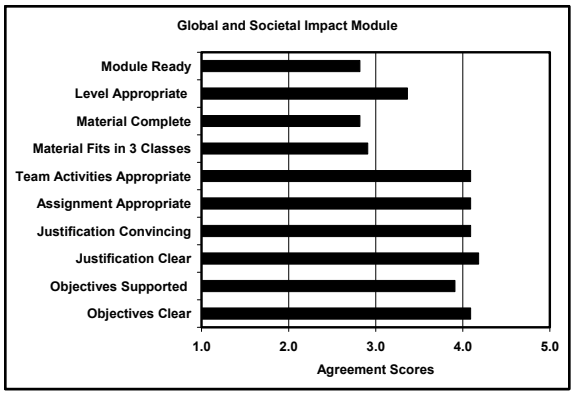

***Figure 5**. Agreement scores for the global and societal impact module*

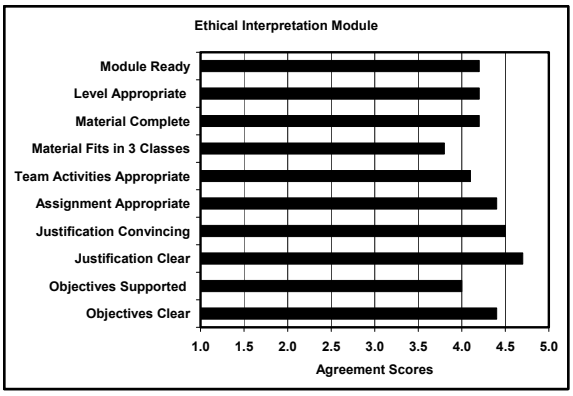

***Figure 6.** Agreement scores for the ethical interpretation module*

Ethical Interpretation Module: Fig 6 shows the agreement scores for the ethical interpretation module. All but one of these scores, including the statement on the readiness of the module, are greater than 4.0, indicating that the students felt that this module was complete, clear, and at the appropriate level. These views were also expressed in written comments from the students. The only statement with a score below 4.0 was that the material fit in 3 classes. Problems here, as indicated by student comments, were twofold. First, the discussions following the case studies, which comprised two of the three 50-minute sessions, were felt to be too freewheeling and open-ended. The module developer has addressed this concern by adding notes in the instructor's guide warning that the instructor may have to be somewhat strict in keeping the discussions on-topic and in ensuring that all issues are addressed. Second, students commented that the reading assignments before the case studies were too long. The module developer has made no changes concerning this comment, feeling that the reading assignments are appropriate to ensure that the students are well informed, a necessity for proper participation in the case studies.

Conclusions

The student evaluations indicated that the objectives and justifications in each module were clear and reasonable and that the classroom material, team exercises, and homework assignments were fairly well done but needed some tweaking. Overall, the students felt that the material needed some work before it was released for general use. In their evaluation of each module, they identified specific weakness and suggestions for improvement. In the following paragraphs, we try to generalize some of these weakness and suggestions.

Many module instructors had difficulty treating all the material in the module in the three 50-minute sessions. In some cases, the amount of material needs to be reduced, but in others the amount is appropriate and the instructor just didn't pace himself or herself correctly. To account

for different instructional paces, the instructor's guide needs to provide more direction to help instructors allocate class time effectively and pace themselves appropriately. This would include a time schedule suggesting the amount of time for each segment of the class and probably a discussion on how to use material for "fast" and "slow" instructors. The instructor's guide also should provide an objective for each segment of the class relating what specific item is most important. Finally, if the module includes alternate paths through the material (e.g., several slides on justification) then the guide should make it clear that the instructor needs to select a subset of the material for class presentation.

In many modules the material may have been a little superficial, and so it needed some additional material dealing with more fundamental ideas and approaches or, perhaps, a few more advanced topics. Also, in some cases lack of clarity of the assignments was a problem and students had difficulty determining what exactly was asked.

Extended in-class exercises can consume a major portion of class time and so the instructor's guide needs to provide considerable structure for them. In particular, it needs a set of clear directions for the exercise and suggestions for efficient, effective student reporting of their results. The reporting phase of team exercises, which can greatly enhance the effectiveness of the exercise, can consume an inordinate amount of time, particularly if all teams are allowed to report fully. The guide, therefore, needs to provide several suggestions for efficient reporting. Sometime multiple short exercises may be better than a single more comprehensive one, particularly when trying to get a class to contribute to the development of a complex idea. This can take the form of a sequence of rhetorical questions to direct the student's comments.

Acknowledgement

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References

1. "Engineering Criteria 2000," Accreditation Board for Engineering and Technology, Inc, 1997.
2. Felder, R. M. , D. R. Woods, J. E. Stice, and A. Rugarcia, (2000) " The Future of Engineering Education: II Teaching Methods That Work," *J. Chem. Eng. Educ.*, vol. 24, no. 1, pp. 26-39.
3. Woods, D. R., A. N. Hrymak, R. R. Marshall, P. E. Wood, T. W. Hoffman, J. D. Wright, P. A. Taylor, K. A. Woodhouse, and C. G. K. Bouchard, (1997) "Developing Problem Solving Skills: The McMaster Problem Solving Program," *J. Eng. Educ.*, vol. 86, no. 2, pp. 75-91.
4. Seat, E. and S. M. Lord, (1999) " Enabling Effective Engineering Teams: A program for Effective Interaction Skills," *J. Eng. Educ.*, vol. 88, no. 4, pp. 385-390.
5. Pimmel, R., R. Leland, and H. Stern, "Changes in Student Confidence Resulting from Instruction with Modules on EC 2000 Skills," *Proc. 2002 ASEE Annual Conf.*, In print.

Biographical Sketches

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