THE FUTURE OF ENGINEERING EDUCATION

Part 3. DEVELOPING CRITICAL SKILLS

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In the first paper in this series[1] we proposed that our goals as engineering educators should include equipping our students with problem-solving, communication, teamwork, self-assessment, change management, and lifelong learning skills. These goals are consistent with ABET Engineering Criteria 2000,[2] currently a consideration of great importance in the United States and (we predict) in other countries in the near future. In the second paper[3] we described a variety of instructional methods that have been shown to improve student learning. In this paper we will consider the application of some of those methods to the development of the desired skills.

Process skills are "soft" skills used in the application of knowledge. The degree to which students develop these skills determines how they solve problems, write reports, function in teams, self-assess and do performance reviews of others, go about learning new knowledge, and manage stress when they have to cope with change. Many instructors intuitively believe that process skills are important, but most are unaware of the fundamental research that provides a foundation for developing the skills, so their efforts to help their students acquire the skills may consequently be less effective than they might wish.[4,5]

Fostering the development of skills in students is challenging, to say the least. Process skills—which have to do with attitudes and values as much as knowledge—are particularly challenging in that they are hard to explicitly define, let alone to develop and assess. We might sense that a team is not working well, for example, but how do we make that intuitive judgment quantitative? How might we provide feedback that is helpful to the team members? How can we develop our students' confidence in their teamwork skills?

Research done over the past 30 years offers answers to these questions. In this paper, we will suggest research-backed methods that will help students to develop critical skills and the confidence to apply them. As was the case for the instructional methods discussed in Part 2,[3] all of the suggestions given in this paper are relevant to engineering education, can be implemented within the context of the ordinary engineering classroom, use methods that most engineering professors feel comfortable with, are consistent with modern theories of learning, and have been tried and found effective by more than one educator.

Research suggests that the development of *any* skill is best facilitated by giving students practice and not by simply talking about or demonstrating what to do.[4-6] The instructor's

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role is primarily that of a coach, encouraging the students to achieve the target attitudes and skills and providing constructive feedback on their efforts. A number of approaches to process skill development have been formulated and proven to be effective in science and engineering education, including Guided Design,[7–10] active/cooperative learning approaches,[3,11–16] Thinking-Aloud Pairs Problem Solving (TAPPS),[17–20] and the McMaster Problem Solving program.[4,18–20]

TABLE 1
Some Evidence-Based Components of Expert Problem Solving[a]

Problem solving is the process used to effectively and efficiently obtain the best value of an "unknown" or the best decision for a given set of constraints when the method of solution is not obvious.[b]

Evidence-based targets	*Progress toward internalizing these targets* 20%	40%	60%	80%	100%
1. Describe your thoughts aloud as you solve problems.					
2. Occasionally pause and *reflect* about the process and what you have done.					
3. Do not expect your methods for solving problems to work equally well for others.[c]					
4. Write things down to help overcome the storage limitations of short-term memory (where problem solving takes place).					
5. Focus on accuracy and not on speed.					
6. Interact with others.[c]					
7. Spend time reading the problem statement.[d]					
8. Spend up to half the available time defining the problem.[e]					
9. When defining problems, patiently build up a clear picture in your mind of the different parts of the problem and the significance of each part.[f]					
10. Use different tactics when solving exercises and problems.[g]					
11. Use an evidence-based systematic strategy (such as read, define the *stated* problem, explore to identify the *real* problem, plan, do it, and look back). Be flexible in your application of the strategy.					
12. Monitor your thought processes about once per minute while solving problems.					

[a] *(© by Donald R. Woods, 1998). Some of the items in this table are derived from material in References 22–24.*
[b] *This process is in contrast to exercise solving, wherein the solution methods are quickly apparent because similar problems have been solved in the past.*
[c] *An important target for team problem solving.*
[d] *Successful problem solvers may spend up to three times longer than unsuccessful ones in reading problem statements.*
[e] *Most mistakes made by unsuccessful problem solvers are made in the definition stage.*
[f] *The problem that is solved is not the problem written in the textbook. Instead, it is your mental interpretation of that problem.*
[g] *Some tactics that are ineffective in solving problems include (1) trying to find an equation that includes precisely all the variables given in the problem statement, instead of trying to understand the fundamentals needed to solve the problem; (2) trying to use solutions from past problems even when they don't apply, and (3) trial and error.*

EIGHT BASIC ACTIVITIES TO PROMOTE SKILL DEVELOPMENT

The following activities promote establishing an effective learning environment for process skill development:

1. Identify the skills you want your students to develop, include them in the course syllabus and (if department faculty agree) the university catalog, and communicate their importance to the students. If developing problem-solving and teamwork skills are among your objectives for a course, include "problem solving" and "teamwork" in the list of course topics in the syllabus and university catalog and allocate time for activities that will provide practice in them.[7,21] Be sure the students understand the relevance of the skills to their professional success, and discuss the skills with the same level of seriousness and enthusiasm that you use when presenting the technical content of the course.

2. Use research, not personal intuition, to identify the target skills, and share the research with the students. Table 1 summarizes evidence-based target problem-solving skills. A more complete compilation of novice versus expert evidence is given by Woods,[22] with more recent evidence also available.[23,24] Target skills have also been identified for communication,[25–28] teamwork,[11,16,29–36] assessment (including self-assessment),[29,37,38] lifelong learning,[4,39–47] and change management.[4,48–52]

3. Make explicit the implicit behavior associated with successful application of the skills. Much processing takes place subconsciously in the head of a skilled practitioner. When asked "How do you do that?" the reply is often "I don't know; it just happens." Our task is to take the skill and behavior apart, discover what is really important (based on research), and communicate it to the students in easily digestible chunks. Illustrative objectives and assessment methods for most skills can be downloaded from the World Wide Web.[7,51]

4. Provide extensive practice in the application of the skills, using carefully structured activities, and provide prompt constructive feedback on the students' efforts using evidence-based targets. People acquire skills most effectively through practice and feedback. No matter how many times students may see a skill demonstrated, they rarely master it until they attempt it and receive guidance in how to improve their performance after each attempt.

There is a temptation for instructors to select their own terminology for problem-solving strategies in their courses. This temptation should be resisted. . . . being exposed to different problem-solving terminology in different courses is a source of confusion to students.

5. Encourage monitoring. Monitoring is the metacognitive process of keeping track of, regulating, and controlling a mental process, considering past, present and planned mental actions. As students are working, ask them to pause periodically and write responses to questions that force them to deepen their problem-solving approach and improve their understanding. For example,

- ▶ Why am I doing this?
- ▶ What really is the problem?
- ▶ What are the constraints?
- ▶ If I was unsuccessful, what did I learn?
- ▶ Am I finished with this stage?
- ▶ What options do I have? Which is most likely to succeed?
- ▶ Can I write down these ideas?
- ▶ Can I use charts, graphs or equations to represent the ideas?
- ▶ If I had a value of ....., how would that help me in solving the problem?
- ▶ Can I check this result?
- ▶ Have I spent enough time defining the problem?
- ▶ What other kinds of problems can I solve now that I have solved this one correctly?

Schoenfeld[52] has shown the importance of monitoring in the development of problem-solving skills.

6. Encourage reflection. Reflection is the metacognitive process of thinking about past actions. For each problem the students solve, each communication they write or team task they accomplish, periodically ask them to write reflections on how they approached the task. For example, Kimbell, *et al.*,[23] report that occasionally asking students to stop the problem-solving process and describe what they are doing improves the problem solving and the quality of the product. For example, students may be asked to respond to questions such as "What did you do?" and "What did you learn about problem solving?" Schon,[53] Chamberlain,[54] Brookfield,[55] and Woods and Sheardown[56] also highlight the importance of reflecting.

7. Grade the process, not just the product. For some assignments, grade *only* the problem-solving process, the team process, or the prewriting process. Grade the reflections, using the target skills (*e.g.,* those listed in Table 1) as the criteria. Some specific examples are available for problem solving[57] and teamwork.[35]

8. Use a standard assessment and feedback form. Departmental instructors should decide on criteria, and the same assessment and feedback forms should be used across the curriculum.

DEVELOPING PROBLEM-SOLVING SKILLS

In addition to the eight basic activities,

• *Use a standard research-based problem-solving strategy across several (and ideally, all) courses in an instructional program.* There is a temptation for instructors to select their own terminology for problem-solving strategies in their courses. This temptation should be resisted. Only a few of more than 150 published strategies are based on research, and being exposed to different problem-solving terminology in different courses is a source of confusion to students. Select an evidence-based strategy such as the six-stage McMaster Problem Solving Strategy: Engage, Define the Stated Problem, Explore, Plan, Do It, and Look Back.[58]

• *Solve some problems in depth.* If you would normally work through four problems in a given period of time, take the same amount of time to solve just one problem and hand out illustrative solutions for the other three. Enrich the experience for the students when you work out the problem: for example, purposely make wrong assumptions so that they eventually realize that "this is not working out." Take time to explore questions like "*What went wrong?*" "*What have we learned?*" "*Now what?*" Ask the students to carry out some of the problem-solving tasks, individually or in small groups. Anonymously display on transparencies students' attempts to carry out specific steps such as identifying the system, defining the problem, drawing a diagram, and creating symbols for unknowns.

• *Help students make connections between the problem statement, the identification of required technical knowledge, and the problem solution.* For example, "We have just solved problem 5.6. Identify the key words in the problem statement that helped you to identify the information needed to solve the problem. Which key words helped you identify the required simplifying assumptions?" Explicitly making such connections helps build problem-solving expertise.[21,59]

Writing Skills

In addition to the eight basic activities, *give assignments that require writing*. Long essays are not required: single paragraphs can be effective at facilitating the development of writing skills and do not impose a heavy grading burden on the instructor. Brent and Felder[60] offer suggestions for brief writing assignments that address a variety of different instructional objectives. In-class writing exercises are particularly valuable in that they provide snapshots of what the students actually do. Students can often be observed following a typical pattern of unsuccessful writing: they sit with pen poised, staring at the paper and waiting for inspiration to strike. Encourage them to brainstorm ideas about the topic and about the target audience and to try to find a match between the audience needs and the topic. Suggest that they free-write without critiquing themselves and then discard sections that don't work.

Teamwork Skills

Many instructors seem to believe that simply giving three or four students something to do together—a laboratory experiment, for example, or a process design project—should somehow enable all of them to develop the skills of leadership, time management, communication, and conflict resolution that characterize high-performance teams. Unfortunately, it is not that easy. What often happens under such circumstances is that one or two students do most or all of the work and all students get the same grade. This promotes a great deal of resentment of both the slackers and the instructor. It does not promote development of teamwork skills.

If promoting teamwork skills is an objective, use a structured approach to teamwork such as *cooperative learning*[11,13,15] in addition to the basic eight activities. The team assignments should be structured to assure positive interdependence (that is, if anyone on the team does not fulfill his or her responsibilities, everyone is penalized in some manner), individual accountability for all the work done on the project, face-to-face interaction (at least part of the time), development and appropriate use of interpersonal skills, and regular self-assessment of team functioning.

Part 2 of this series[3] offered suggestions for meeting the defining criteria of cooperative learning and for overcoming the resistance that some students initially feel toward the approach. The following procedures help make students aware of several of the requisites of good team functioning:

• *Assign a chairperson/coordinator for every meeting.* Research has shown that groups function better if a designated chairperson coordinates arrangements. The chair's tasks are to schedule meetings, to make sure that all team members know what they are supposed to do prior to each meeting, and to keep everyone on task. Research also shows that the chair's role differs from the role of leader[33]—someone who holds greater decision-making authority than the other team members—although serving as chairperson helps develop leadership skills. (We do not recommend including the role of leader in team activities.) Require the chairperson to prepare and circulate an agenda ahead of time and ask the group to give written feedback to the chair at the end of each meeting. The chairperson can use this input to reflect on his/her skill and to set targets for improvement.

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• *Have the group hold a "norms" meeting soon after they are formed.* Ask the teams to hold a meeting at which they decide on group behavior norms, reaching consensus on specified questions such as "*What is the role of the coordinator?" "How will we handle missed meetings and lateness?" "How will we make decisions?" "How will we deal with team members who repeatedly fail to meet their responsibilities?" "How will we deal with conflicts that develop in the group?*" The teams should summarize their norms on a sheet of paper, sign it, and turn a copy in to the instructor. Several weeks later, the instructor might return the copy and ask them to reflect on how well they are meeting the norms. A checklist of 17 items that should be addressed in establishing norms is available.[7]

• *Ask students to complete inventories such as the* Myers-Briggs Type Indicator,[61] FIRO B,[31,62] Johnson's conflict inventory,[63] or the Index of Learning Styles.[64] Suggest that team members share their results and discuss the implications, making sure they are aware that the most effective groups include people with different styles. Although differences might lead to apparent conflict, they can be used to bring a synergy to group activities that might otherwise be unattainable.

• Incorporate formal team-building exercises as part of your implementation of cooperative learning.[16]

Self-Assessment Skills

In addition to the basic eight activities,

•*Have the students write resumes.* Although workshop activities can develop self-assessment skills, a concrete activity such as writing a resume is an excellent way to put the skill to practical use.

• *Include self-assessment as part of what you do to help develop any other skill.* Combine writing, reflection, and self-assessment by requiring students to submit their analysis of evidence of skill mastery gathered from classwork and other applications of the skills. Examples of such reports are available on-line.[7] Data show that self-assessment tends to correlate with external assessments of skill mastery.[7,51,65]

Lifelong Learning Skills and Problem-Based Learning

The learning process may be broken down into the following tasks:[66]

- Sense problem or need
- Identify learning issues
- Create learning goals and assessment criteria
- Select resources
- Carry out the learning activities
- Design a process to assess the learning
- Do the assessment
- Reflect on the learning process

In traditional instruction, the student is responsible only for the fifth of these tasks (learning activities), the last task (reflection) is usually omitted, and the instructor takes responsibility for the remaining tasks. *Lifelong learners*, on the other hand, take some responsibility for performing all of the tasks themselves.

One approach is to focus one of the eight tasks on lifelong learning. For example, cooperative groups could be asked to "identify the learning issues" in a problem. Another more ambitious option is to *convert "reporting back" to "teaching."* When students have completed an independent study or a research project, they typically report back by giving a speech. The class listens with varying degrees of interest. The dynamics change if the student *teaches* the material to a small group. The audience listens intently and asks questions, because now each of them is expected to *learn* the material being presented. The student speaker becomes the teacher. He/she learns and applies the ideas offered in Part 2 of this series[3] and receives the benefits of those that will be presented subsequently in Part 4 (how to train the teachers).

Perhaps the most ambitious option for promoting the development of skills in most of the tasks is called *problem-based learning* (PBL).[47,66,67] Problems and projects can be incorporated into a course in a variety of ways. At one extreme is the traditional approach in which problems are given at the end of each text chapter and homework is assigned after the professor has lectured on the subject. The role of the problems is to help students deepen their understanding of previously-acquired knowledge. In contrast, when PBL is used, the problem is posed *before* the students have acquired the knowledge needed to solve it. This inductive ordering simulates the research environment: the students begin with a problem and then proceed to figure out what they need to know, create hypotheses, read the literature and/or search the Web, talk to experts with related knowledge, acquire critical information through modeling, experimenting and discovering, and finally solve the problem. The approach may be applied in any educational setting including lecture classes, laboratory courses, and design courses.[68]

Once a problem has been posed, different instructional methods may be used to facilitate the subsequent learning process—lecturing, instructor-facilitated discussion,[51] guided decision-making,[8–10] or cooperative learning.[3,11,13–16] As part of the problem-solving process, student groups can be assigned to complete any of the learning tasks listed above, either in or out of class. In the latter case, three approaches can be adopted to help the groups stay on track and to monitor their progress: (1) give the groups written feedback after each task, (2) assign a tutor or teaching assistant to each group, or (3) create fully autonomous, self-assessed "tutorless" groups.

Guided decision-making[8–10] is a model for the first option. The instructor anticipates how groups might handle each learning task and creates written feedback to guide the process. This approach was designed to allow one instructor to manage many groups at a time. It has been used successfully in the teaching of engineering design at the University of West Virginia[68] and of pharmacy at Purdue University.[69] Option #2—assigning a tutor to each group of four to seven students—has been used extensively in the health sciences.[43,46]

Option #3 is used when a tutor cannot be provided for each group (a common situation in engineering) and/or when the goal is to move students away from dependence on the instructor toward independence and interdependence. Each group is trained and empowered with process skills (described previously in this paper); the groups monitor and self-assess their work; and the instructor establishes conditions to aid the groups in self-management.[7,70] The instructor should select a technical topic that would normally be "lectured" on for about three weeks, and use PBL to address it instead. The instructor's role is to create the environment, monitor the students' progress, and help them reflect on the lifelong learning skills they are developing. Illustrative student reflections and self-assessments are available,[7] as are more examples of how to move gradually into a full PBL model.[51] This approach has been used successfully in engineering, science, and pharmacy education.[4,71–73]

Extensive evaluation of small-group, self-directed, self-assessed, interdependent (cooperative) problem-based learning has been reported for medical schools.[44–46] National Board Medical Examination scores earned by students in such programs were compared with scores earned by students in conventional programs. The experimental group scored lower on the exams testing basic science, while the opposite result was observed for the exams testing medical problem solving. The differences were statistically significant. The students who participated in a PBL program exhibited a greater tendency to adopt a deep (as opposed to surface or rote) approach to learning,[74–77] a greater mastery of interpersonal and lifelong learning skills, and greater satisfaction with the learning experience. Positive program evaluations of the McMaster Problem Solving program in engineering[4] and of the Guided Decision-Making Model[10] have also been reported; however, the role of PBL in attaining these outcomes could not be easily determined because the programs studied involved multifaceted skill development efforts.

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Change-Management Skills

People inevitably encounter unexpected and stressful changes in their lives, but successful people are able to cope with the changes in such a way that they emerge with renewed or even greater strength in performance, self-confidence, and interpersonal relationships, even if they initially experience losses in these domains. Stressful changes that students might experience include leaving home for the first time, being exposed to unaccustomed intellectual challenges, being thrust into a student-centered learning environment in which the instructor can no longer be counted on to supply all required knowledge, and making the transition from an academic world to the professional world.

Perry's Model of Intellectual Development[40,67,78,79] (or an equivalent model such as King and Kitchener's *Model of Reflective Judgment*[80]) provides a good framework for helping students cope with the expectations of the new learning environment. According to William Perry, a Harvard psychologist, college students progress through some or (in rare cases) all of the following stages of development.

- Level 2 (Dualism). Every point of view is either right or wrong. All knowledge is known and obtainable from instructors and texts, and the student's task is to absorb what the instructor presents and demonstrate having done so by repeating it back. Confusion occurs if the text and the instructor do not agree. Dualists want facts and formulas and don't like theories or abstract models, open-ended questions, or active or cooperative learning.

- Level 3 (Multiplicity). Most information is known, but there are some fuzzy areas with questions that have no answers yet but eventually will. The instructor's dual role is to convey the known answers and to teach students how to obtain the others. Students start using supporting evidence to resolve issues rather than relying completely on what authorities say, but they count preconceptions and prejudices as acceptable evidence, and once they have reached a solution they have little inclination to examine alternatives. Open-ended questions and cooperative learning are still resented, especially if they have too much of an effect on grades.

- Level 4 (Transition to relativism). Some knowledge is known but some is not and probably never will be. Students feel that almost everything is a matter of opinion and that their answers are as good as the instructor's. The instructor's task is to present known information and to serve as a role model that can be discounted. Independent thought is valued, even if it is not substantiated by evidence, and good grades should be given to students who think for themselves, even if they are wrong.

- Level 5 (Relativism). Knowledge and values depend on context and individual perspective rather than being externally and objectively based, as Level 2–4 students believe them to be. Using real evidence to reach and support conclusions becomes habitual and not just something professors want them to do. Different knowledge is needed and different answers are correct in different contexts; there is no absolute truth. The student's task is to identify the context and to choose the best answers for that context, with the instructor serving as a resource. Students at this level are comfortable with corrective feedback.

TABLE 2: Reflection on and Self-Rating of Skill Development Strategies

Reflection: ____________________

	Already Do this	*Should Work*	*Might Work*	*Not My Style*
Problem solving skill				
Value the skill: make it an explicit outcome of your course	O	O	O	O
Hand out research evidence for the skill	O	O	O	O
Make implicit behavior explicit: list goals and criteria	O	O	O	O
Use student reflection and monitoring	O	O	O	O
Grade (mark) the problem-solving process	O	O	O	O
Use standard assessment and feedback forms	O	O	O	O
Solve some problems in depth	O	O	O	O
Use a common strategy for problem solving	O	O	O	O
Other ____________________	O	O	O	O
Communication skill				
Value the skill: make it an explicit outcome of your course	O	O	O	O
Hand out research evidence for the skill	O	O	O	O
Make implicit behavior explicit: list goals and criteria	O	O	O	O
Use student reflection and monitoring	O	O	O	O
Grade the communication process	O	O	O	O
Use standard assessment and feedback forms	O	O	O	O
Require in-class writing	O	O	O	O
Other ____________________	O	O	O	O
Team skill				
Value the skill: make it an explicit outcome of your course	O	O	O	O
Hand out research evidence for the skill	O	O	O	O
Make implicit behavior explicit: list goals and criteria	O	O	O	O
Use student reflection and monitoring	O	O	O	O
Grade the teamwork process	O	O	O	O
Use standard assessment and feedback forms	O	O	O	O
Assign a chairperson for every meeting	O	O	O	O
Start with a "norms" meeting	O	O	O	O
Other ____________________	O	O	O	O
Self-assessment skill				
Value the skill: make it an explicit outcome of your course	O	O	O	O
Hand out research evidence for the skill	O	O	O	O
Make implicit behavior explicit: list goals and criteria	O	O	O	O
Use student reflection and monitoring	O	O	O	O
Grade the self-assessment process	O	O	O	O
Use standard assessment and feedback forms	O	O	O	O
Require resumé writing	O	O	O	O
Other ____________________	O	O	O	O
Lifelong learning skill				
Value the skill: make it an explicit outcome of your course	O	O	O	O
Hand out research evidence for the skill	O	O	O	O
Make implicit behavior explicit: list goals and criteria	O	O	O	O
Use student reflection and monitoring	O	O	O	O
Grade the process	O	O	O	O
Use standard assessment and feedback forms	O	O	O	O
Use structured cooperative learning groups	O	O	O	O
Use guided decision-making	O	O	O	O
Use small group, self-directed, self-assessed PBL	O	O	O	O
Other ____________________	O	O	O	O
Change management skill				
Value the skill: make it an explicit outcome of your course	O	O	O	O
Hand out research evidence for the skill	O	O	O	O
Make implicit behavior explicit: list goals and criteria	O	O	O	O
Use student reflection and monitoring	O	O	O	O
Use the grieving-process model	O	O	O	O
Use the Perry inventory to guide students	O	O	O	O
List new opportunities afforded by the change	O	O	O	O
Run a change management workshop	O	O	O	O
Other ____________________	O	O	O	O

• Higher levels (6–9) involve the development of commitment to an internally-based system of values. Most entering college students can be found on Levels 2 or 3, and relatively few attain Level 5 by the time they graduate.

Students being asked to function at a level higher than their current level are likely to be under a great deal of stress, especially if the two levels are not adjacent. Their reactions to this stress account for much of the resistance and occasional hostility instructors often encounter when they begin to use student-centered teaching methods like cooperative and problem-based learning.[66,81] If students learn strategies for managing the stress associated with the transition to student-centered instruction, they may be better able to deal with the stressful professional and personal situations they will inevitably encounter later in their lives.

Strong justification for helping students learn to cope with change is the all-too-common situation wherein a well-intentioned faculty member hears about problem-based or cooperative learning and simply launches students into it, with little or no explanation or preparation. The outcomes of such experiments often include student anger and frustration, petitions to the department head, and terrible student ratings. One can hardly blame instructors in this situation for going back to more conventional teaching, to the ultimate detriment of their students. When students are helped to prepare for change, it may not eliminate their unhappiness about it but they are likely to tolerate it long enough to begin to see the benefits.

The first six of the eight basic activities described previously apply to the development of change-management skills. In addition,

• *In class or in your office, tell students about the stages of reaction to stressful change.* People who find themselves in highly stressful situations may go through some or all of the stages that have been associated with the grieving process: shock, denial, strong emotions, resistance and withdrawal, acceptance, struggle, better understanding, and integration.[66,81] Students undergoing this process may find it helpful to know how the process works, and more to the point, that it eventually ends. You might also take a few minutes to elaborate on how the students can use the same stage model to help them manage other stressful situations such as death of a friend or relation or the loss of a job. Doing so is another way to demonstrate concern about their careers and lives beyond the confines of the classroom, which is one of the hallmarks of effective teaching.[3]

• When using student-centered instruction, acknowledge to the students that it may be stressful to some of them but make it clear that you are doing it for good reasons. If possible, get them to come up with benefits themselves. For example,

In this course we will be using extensive cooperative learning, following the rules and procedures in the syllabus that we just outlined. Hundreds of research studies have shown that this approach leads to some real benefits for students. Form groups of three and make a list of what those benefits might be. Then I'll tell you what the research shows and we'll see how many of them you get."

• Run a workshop on the management of change.[4,7]

SUMMARY

• Transmitting knowledge is the easiest part of teaching; far more challenging is the task of equipping students with the critical skills they will need to succeed as professionals and responsible members of society. The following strategies have been recommended to help achieve this goal:

1. *Identify the skills you wish your students to develop and communicate their importance to the students.*
2. *Use research, not personal intuition, to identify the target skills. Share some of the research with the students.*
3. *Make explicit the implicit behavior associated with successful application of the skills.*
4. *Provide extensive practice in the application of the skills, using carefully structured activities. Provide prompt constructive feedback on the students' efforts.*
5. *Encourage monitoring.*
6. *Encourage reflection .*
7. *Grade the process, not just the product.*
8. *Use a standard assessment and feedback form.*

Additional suggestions have also been given that apply specifically to the development of problem-solving, writing, teamwork, self-assessment, lifelong learning, and change-management skills.

IF YOU GET ONE IDEA FROM THIS PAPER

Focusing lectures, assignments, and tests entirely on technical course content and expecting students to develop critical process skills automatically is an ineffective strategy. Instructors who wish to help students develop problem-solving, communication, teamwork, self-assessment, and other process skills should explicitly identify their target skills and adopt proven instructional strategies that promote those skills. We suggest that you reflect on the strategies listed in Table 2 and rate their potential applicability to your teaching.

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