the MPS program: the McMaster Problem Solving program

1. What is problem solving?

2. The MPS program

3. Design of an MPS unit

4. MPS Units 1 to 18: focus on individuals solving relatively well-defined problems

1. Awareness
2. What is Problem Solving?
3. Self-assessment
4. Strategies
5. I want to and I can: Stress Management
6. Analysis: classification
7. Creativity
8. Introduction to visual thinking: translation
9. Define the stated problem
10. Getting Unstuck
11. Identifying Personal Preference and Implications
12. Learning Skills
13. Analysis: Consistency
14. Creating the Look Back and Extending Experiences
15. Exploring the Situation to Identify the Real Problem
16. Tactics:
17. Time Management for Individuals
18. Evaluation and Stress Management.

5. MPS Units 19 to 29 (and 52): focus on interpersonal skills and group problem solving

19. More on Visual Thinking: Reading P&IDs
20. Asking Questions
21. Analysis: Sequences and Series
22. Broadening Perspectives.
23. Obtaining Criteria.
24. Decision making.

23-24a. Criteria and Decision making in the context of career Counselling and Guidance.

25. Time Management for groups and projects.
26. Listening and Responding:
    a) Attending and following
    b) Body language.
    c) Reflecting
27. Group Skills.
28. Group Evaluation.
29. Chairperson skills

52. Fundamentals of interpersonal skills

6. MPS Units 30 to 57: focus on solving messy problems

30. Analysis: Reasoning and Drawing Conclusions
31. Defining Real Problems
32. Implementing
33. Coping with Ambiguity:
34. Trouble Shooting
35. Heuristics or Rules-of-thumb for Problem Solving:
36. Self-Directed Learning: or Problem-based Learning
37. Simplifying and Generalizing:
38. Consolidating the Knowledge Structure:

38a. Consolidating the Knowledge Structure in Chemical Engineering:

39. Creating Tacit Information or Experience Knowledge:

39a. Creating Tacit Information or Experience Knowledge in Chemical Engineering:

40. Successive Approximation and Optimum Sloppiness:
41. Finding Opportunities
42. Procrastination and other Attitudes:
43. Giving and Receiving Feedback
44. Assertiveness
45. Coping Creatively with Conflict
46. Coping with Difficult Behaviours
47. Accentuating the Negative
48. Communication:
49. Coping with Change:
50. Being a Change Agent
51. Managing Change
52. Fundamentals of Interpersonal skills (see previous grouping)
53. Effective Teams and Team building

54. Goals, Mission and Vision
55. Roles and Responsibilities in Teams
56. Networking: How to enrich your Life and Get Things Done
57. Convincing Others: Getting a Buy-in
58. Leadership

Picture of students in the MPS 4: Strategy unit

the MPS program: the McMaster Problem Solving program

1. Introduction to Problem Solving

Why are problem solving skills needed? What is the challenge to develop these skills? How does the MPS definition of problem solving compare with critical thinking? How does a program to develop problem solving skills differ from an Inquiry program? a Problem-based Learning, PBL, program? What is the difference between problem solving and exercise solving? In this introduction each is considered in turn.

1.1 The Need for Process Skills

Higher order thinking, problem solving, communication, team work and lifetime learning skills - these are some *process skills* that students expect to get from their high school and university programs (Boud and Lublin, 1983; Bradford, 1984). Several reports have suggested that current undergraduates and graduates both need but do not possess these abilities (Rush et al., 1985; Sparkes, 1989; Resnick, 1987; Woods and Crowe, 1984). Indeed, probably no teacher exists who does not try to develop problem solving and clear thinking in their students. So what's the problem?

1.2 The Challenge to develop process skills

These so-called *soft skills* are really the *hard skills* to develop. Developing student's confidence and skill in process skills is extremely challenging. The usual methods that good-intentioned teachers use, but that are relatively ineffective, are: for *problem solving*:

Ineffective approach #1. give the students open-ended problems to solve; *This, we now see, is ineffective because the students get little feedback about the process steps, they tend to reinforce bad habits, they do not know what processes they should be using and they resort to trying to* ***collect sample solutions and match past memorized sample solutions to new problem situations.***

Ineffective approach # 2. show them how you solve problems by working many problems on the board and handing out many sample solutions; *This, we now see, is ineffective because teachers know too much. Teachers demonstrate "exercise solving". Teachers do not make mistakes; they do not struggle to figure out what the problem really is. They work forwards; not backwards from the goal. They do not demonstrate the "problem solving" process; they demonstrate the "exercise solving" process. If they did demonstrate "problem solving" with all its mistakes and trials, the students would brand the teacher as incompetent. We know; we tried!*

Ineffective approach #3. have students solve problems on the board; *Different students use different approaches to solving problems; what works for one won't work for others. When we used this method as a research tool, the students reported* ***"we learned nothing to help us solve problems by watching Jim, Sue and Brad solve those problems!"***

Through four research projects we identified why and how these and other teaching methods failed to develop process skills and which methods were successful in developing the skills (Woods et al., 1975; Woods et al., 1979; Woods, 1993a,b,c).

Similarly, putting students in groups and expecting them to develop *group skills* is ineffective. Changing the environment and expecting students to develop *change management skills* is ineffective.

We want to develop both confidence and skill. The research of Bandura (1982) on eliminating people's phobias is illuminating. A person is afraid of snakes or afraid of heights. Bandura found that an effective approach is:
break the task into parts, give them opportunities to try a small part, give them immediate and positive feedback plus one or two areas to work on, offer as models the approach taken by successful persons.

Chamberlain's research (1978) was on people wishing to

change- to stop their *self-defeating behaviours*. They wanted to stop smoking, lose weight. The approach was to set goals and write extensively in a journal. Kimbell et al. (1991) and Schon (1987) also showed that the development of skill required journal writing.

1.3 Problem solving versus critical thinking

Think clearly, think critically, problem solve, make good decisions – are these all the same? The skills are about the same; it's more a discussion of definition of terms. Let's face it; we want our students to have all these thinking abilities. However, if we are considering the various resources and resources programs available, I need to put the MPS program in the context of these other programs.
The critical thinking movement, pioneered by Richard Paul (1992) and sustained by the annual Sonoma Conference, is philosophy-based. The program started as an outgrowth of Informal Logic courses given by Departments of Philosophy. This expanded to include attitudes and suggests that problem solving is one of the avenues where critical thinking is used. The MPS program draws on both the philosophical and the cognitive/psychological research. It uses the generic term "Problem Solving" to represent the application of a range of attitudes and thinking skills that includes more than Critical Thinking. MPS unit 30 focusses on the development of this skill. Diane Halpern's text (1996), although more psychologically based than the philosophically based book of Paul, helps gives elaborate on the role of critical thinking.

1.4 Problem solving versus Inquiry programs

Although many different definitions have been used to describe Inquiry programs, many have evolved from the critical thinking base. The main goal of the experience is to help the students pose interesting questions; pose questions that will allow research into many differ viewpoints; research to resolve situations where there are a variety of completely different viewpoints. The programs may or may not have a subject knowledge component: that is 50% new subject knowledge and 50% on thinking skill development. <http://socserv2.mcmaster.ca/~fss/inquiry/artofinq.htm, >

1.5 Problem solving versus problem-based learning

Problem-based learning is a learning environment where a problem situation is posed first; the students need to identify what they need to know to solve the problem; they learn it and use the new knowledge to solve the problem. The opposite is "subject-based Learning" where the students are told what they need to know, a course outline is provided, often a required text is specified and the teacher "lectures" and the students solve problems afterwards. The Problems are at the **end** of the Chapter and not at the **start.**

For PBL to succeed, either the tutor or the students or both should have process skills. Rarely does PBL develop process skills, except for lifetime learning. Rarely does PBL develop group skills, or develop problem solving skills. You need the process skills for PBL to work effectively. McMaster medical school, for example, only admits students who can demonstrate those skills through their simulated tutorial screening process.
<http://chemeng.mcmaster.ca/innov1.htm>

1.6 Problem solving, pattern recognition versus exercise solving

An *exercise* is a situation that, by pattern recognition, the person recognizes as being similar to a problem that he/she remembers solving successfully in the past. To solve the new situation, the persons recalls and applies the past solution. Of 100 "problem situations" encountered by persons with about 10 years experience in their specialty over 90 of them are *exercises*. They rarely encounter "problems"

A problem is a situation where the person cannot recall any past solved situation that bears any resemblance to the situation. They are unsure or what the problem really is and of how to tackle it. They make a lot of mistakes. They try many different options and "see what happens". They become distressed. They need to brainstorm many ideas. They try simpler versions of the problem.

Whether a situation is a problem or an exercise depends on the person and his/her experience.

We have interacted with A+ students who claim they are great at problem solving: Pete says
" I have successfully solved 3000 "problems" in my University program." What Pete is good at is pattern recognition and exercise solving. All of us need skill in pattern recognition and exercise solving. However, Pete and his A+ friends have really had very little practice in problem solving. When we really check their experience

we find that they had to solve about 250 “problems”. The rest, 2500, were exercises to them. Pete really needs to improve his “problem solving” skill.

1.7 Problem solving and subject knowledge

We need subject knowledge to solve problems. Chemists need to know chemistry to solve problems in chemistry. But, people can know the subject knowledge not be able to solve problems in that subject. To solve problems we need both generic or general problem solving skill **and** subject knowledge. We also know that the subject knowledge needs to be memorized in readily-accessible patterns.

Research has shown that courses in problem-solving skill alone are rarely successful.

2. The MPS Program to develop problem solving (and other) skills

What is the MPS program? How does the MPS program relate to PBL? How do we know that the MPS and PBL approaches are effective?

2.1. What is the MPS program?

The MPS program is constructivist, in that the MPS program builds on the student’s previously-developed skills and attitudes; provides feedback and awareness of what those are and then provides practice with feedback to alter the skill toward target skills.

The MPS program is behaviouralistic in that the MPS program is grounded on behavioural objectives with measurable criteria for each skill set. Indeed, the amount of detail in the objectives is much more extensive than many of the available programs. For example, Alverno College’s superb program identifies about 40 subobjectives for “problem solving” . We have identified about 150 for problem solving.

The MPS program acknowledges the need to blend generic problem solving skills with the subject knowledge. The generic problem solving skill is first

built by focussing on the skill in a general subject; content-independent environment. We tried building the skill initially in the context of Chemical Engineering. We failed. “We are not sure whether we don’t have the problem solving skill or we don’t know Chemical Engineering,” complained the students. Hence, the **build** component of all the MPS materials have been used from Grades 4 through advanced Management courses; in the context of French, Girl Guiding, Electrical contraction, Physics, Chemistry, Math., Nursing, Occupational Therapy, Policing, Business, English, Accounting, Forestry, Funeral Directors, Ambulance Service, Medical Doctors, and Administration

Bridge the skill by requiring students to apply the built skill in *simplified* problems or exercises in your subject discipline. Although we have a collection of problems in a range of subject disciplines, most who want to implement the MPS program will need to develop this material in the subject discipline. Some examples are given in Woods (1997) “Problem based Learning: Resources to gain the most from PBL,” Chapter A available from
<http://chemeng.mcmaster/innov1.htm

Extend the application of the skill to everyday problem situations in one’s personal life and to difficulty problem in the subject discipline. Here, we depend upon extensive reflective journal writing by the students/participants as evidence of efforts. This means that for the MPS program to be effective, continual journal writing and reflection are key components. Some examples are given by Woods (1997) “Problem-based learning: Resources to gain the most from PBL,” Chapter F.

Over the past 25 years, we have defined these process skills, identified effective methods for developing student's process skills, implemented a series of four, required courses to develop the skills and evaluated the effectiveness of the program. We identified 57 general component skills and focussed on the development of 37 of these in the time we have available. Table 1 lists the units. We use 120 hours of workshops spread over four required courses to develop the skills. Each skill is built (using content-independent activities), bridged (to apply the skill in the content-specific domain - such as Chemical Engineering) and extended (to use the skill in other contexts and contents and in everyday life). Tests and examinations of process skills, TEPS, were developed to assess the degree to which the students can apply the skills. We call this program of 120 hours of integrated workshops the McMaster Problem Solving (MPS) program.

Table 2 lists the process skill, the names of the major MPS units that develop that skill (plus names of pertinent

units whose prime goal is to develop other skills) and the course sequence. The amount of time required depends on the class. Some skills are honed concurrently in several units so that the number of in-class workshop hours and the hours in the courses are not consistent.

Details about the program are reported elsewhere (Woods et al., 1984; Woods, 1987; Woods, 1992, Woods et al. 1997).

2.2 How does the MPS program relate to PBL?

We find the problem-based learning environment to be one of the most effective media to develop our student's skill in lifetime learning. In addition, we believe that small group, self-directed, self-assessed PBL promotes better learning and retention of the subject knowledge. So, small group, self-directed PBL workshops are required parts of courses #3 and 4 when the students are learning the chemical engineering subjects "process safety and engineering economics." We wish we could use this learning environment for other subjects in the curriculum. What is delaying us is:

- We feel that our students need to have a high degree of process skill development before we use PBL (more specifically, we need about 80 hours of workshops first before using the PBL format)

- Our faculty resources are limited so that we cannot provide one tutor for each group of five to six students. Hence, we work with tutorless groups so that one instructor can manage five to ten groups of students simultaneously (Woods, 1991; 1996; Woods et al., 1996).

Hence, in the MPS program we use small group, self-directed PBL
1. To develop the process skill of "lifetime learning", and
2. So that students learn "more effectively" some chemical engineering subject knowledge.

We do **not** use small group, self-directed PBL until after a basic core of "process skills" have been developed through the MPS program so that we can then work with tutorless groups.

2.3 How do we know that the MPS and PBL approaches are effective?

We have evaluated the MPS program from eight different perspectives: 1) marks improvement in other courses, 2) student acceptance of the learning environment, 3) student's confidence in their problem solving skills, 4) their skill in problem solving 5) their attitude toward lifetime learning, 6) development of self-assessment skill, 7) alumni, recruiter and employer response and 8) student and faculty acceptance.

2.3-1 Marks improvement in other courses

In our program, Chemical Engineering and Applied Chemistry students take a required, 4-credit course on the "principles of chemical engineering" in the second semester of the second level. We set up the new curriculum in the fall of 1982. Chemical Engineering students were required to take course #1 in problem solving concurrently with a convention, subject-based "principles" course. The Applied Chemistry students did not take course #1 and therefore served as the control group. We used marks for both groups before 1982 (before the treatment) and the pooled marks for 1982-83 and 1983-84 when the chemical engineering students received the problem solving courses and the control group did not. For both groups we measured the difference between the marks in "principles" course after 1982 and before 1982. The null hypothesis was that the difference in Chemical Engineers marks before and after 1982 would be the same as the difference in Applied Chemists marks before and after 1982. In other words, the problem solving course would have no significant effect on the students' marks in the "principles" course. Based on a t-test, the probability that the marks between the two groups differ by chance alone is 5.9%. Although not conclusive, this is a good indication that an improvement in marks in the "principles" course occurred because the students took the concurrent course in problem solving.

2.3-2 Learning environment. The students' assessment of the learning environment was measured by the Course Perceptions Questionnaire (Knapper, 1994; Ramsden, 1983). The student's perceptions of the learning environment within our department (the sum of the quality of teaching, openness to students, freedom in learning, clarity of goals, standards and assessment, vocational relevance, social climate with negative loadings for workload and degree of formal teaching methods) was 29.68 compared with a control group in our engineering faculty with a rating of 16.2. This is statistically significant ($t = 5.3$, $p<0.0005$). Why is a high rating important? Ramsden (1983, 1982) used the

workload, freedom and quality of teaching elements to define "student-centered" characteristics of departments. In student-centered departments, Ramsden found that students were more likely to develop a "deep" approach to learning than a "surface or rote memorization" approach ($p<0.01$). Students rated the MPS program in our Department more student-centered than in the control department ($t = 2.54$, $p<0.01$).

2.3-3 Confidence with problem solving skills. We used Heppner's PSI inventory (Heppner and Peterson, 1982). Our data show that Canadian university engineering students (without the MPS training) show no significance increase in confidence between their sophomore and senior years ($t=0.26$; $p<0.4$). However, those students in the MPS program, although they have the same scores in the sophomore year, have significantly improved scores in the senior year. When we follow the same series of cohorts of students starting in 1988, the values are ($t= 5.0$; $p<0.0005$), ($t=3.53$; $p<0.001$), and ($t=2.77$; $p<0.01$). Instead of following specific cohorts of students through the program, we also pooled all the sophomore and senior Chemical Engineering data for students who received the MPS program. The pooled results show that the MPS program made a significant improvement in the student's confidence ($t=13.18$; $p<0.0005$) whereas the control students (who received no treatment) had negligible improvement in confidence.

2.3-4 Skill with process skills In each of the three years, students wrote two or three-hour written examinations, TEPS, assessing their processing skills. Class average marks were 60% to 87% over the past 10 years. In addition, with the Billings-Moos Coping Responses Inventory (Billings and Moos, 1981) students from the MPS program showed, between their sophomore and senior year, a negligible decrease in avoidance ($t = 1.1$; $p<0.15$) and a significant increase in problem solving ($t = 2.85$; $p<0.0025$). In this test, Billings and Moos reported that problem avoidance and problem solving were the significant factors affecting one's ability to cope. For avoidance, a small value was wanted; for problem solving, a large value.

2.3-5 Attitude toward lifetime learning. We used the Perry inventory (Woods, 1994 Chapter 1) to measure student's attitude toward assuming responsibility for their learning. Allen (1981) reported that college freshmen have mean scores of 2.3 to 3.1. Fitch and Culver (1984) report data for seniors in the range 2.8 to 3.1. For students in the MPS program the Perry inventory changed from an average of about 3.5 in third year to an average of about 4.6 in the final year.

We also developed peer and self-tests, called the Quality of Learning Index QLI. The QLI assesses the degree to which students function effectively in small-group, self-directed, interdependent, self-assessed problem-based learning (Woods 1996). In the QLI, each student assesses (and provides evidence to substantiate that assessment) the learning preferences of peers in their cohort PBL groups. We found the inter-reliability of the test to be high (Woods, 1996).. That is, within each PBL group the self and peer assessments agreed. The results for students in the MPS program were that, after six weeks of PBL activity, over 70% of the PBL groups have more that half the members demonstrating skill and attitude consistent with our definition of lifetime learners. That is, over 70% of the groups had QLI>50. Having lifetime learning skill and attitude is important because a) such skill is a valued outcome of the MPS program and b) the quality of the student learning in groups with high QLI is significantly better. For example, in the MPS program, PBL groups are created such that each group had approximately the same grade point average. After six weeks of PBL activity, we measured the QLI for each PBL group. An effective group has a QLI of 100 where all five members work demonstrate lifetime learning skills. Ineffective groups might be those where only two of the five members work as interdependent self-directed learners (QLI of 40). Our research showed that effective groups scored 10 marks higher on subject knowledge examinations than did ineffective groups.

We used TEPS, described above, to assess the student's skill in the different elements of lifetime learning.

2.3-6 Self assessment skill development: When students are skilled in self-assessment their self-marks should "agree" with the benchmarks from an independent, objective observer. Skill in self-assessment is a valued outcome of the MPS program. Furthermore, we wish to empower students with much of the assessment process in our chemical engineering program because we feel that that improves their learning. Stefani (1992) reported that 76% of student's self-assessment marks are within ± 10% of the benchmarks, 23% are underestimated with >-10% and 1% overestimated, with marks >10% above the benchmarks. In the MPS program, we found that 98% of student's self-assessment marks were within ± 10% of the benchmarks, with 2% as underestimates of performance. Hence, the outcomes from the MPS program are much better than those reported by Stefani (1992). Our data can

be expressed in other terms. About 78% of our student's self-assessment marks are within ±5% of the benchmarks, with 9% underestimated and 13% overestimated relative to the benchmarks. We believe these data demonstrate that our students have acquired skill in self-assessment.

2.3-7 Alumni and recruiter response. We completed a blind survey of graduates one to five years from the program (N=48). We asked them to identify "The courses that were the most important for their current professional progress." The results were that 58% of the alumni cited the process skills and PBL courses in our curriculum. The other courses cited were "engineering fundamentals" (25%); project work (10%) and the remainder identified individual courses, such as the environmental course, or the statistics course. On the blind survey, here are typical comments, "If you learn nothing else in Chemical Engineering, remember everything you learn in the process skills courses #1, 3 and 4." "The problem solving that is developed from Day 1 in the Chemical Engineering program is one of the tools that puts the McMaster graduate above engineers from other schools." "The processing courses give me a bit of an edge."

Alumni and students have written articles (Lieske, 1983; Moore et al., 1979; Liebold, B.G. et al., 1976; Chornenko, et al., 1979; and Bouchard, 1996) and have written directly to us about their undergraduate experience. "I consider my experience as an undergraduate in the MPS program invaluable; I simply could not do what I do without having developed critical problem solving skills. My career demands that I am constantly up-to-date on technology and that I always learn new ways to apply fundamentals to the pharmaceutical industry. While much of the base knowledge is technical, a large portion involves using fundamentals to solve difficult, open-ended problems. This type of work takes much more than a knowledge of "type" problems (where the problem is essentially solved by combining past-solved exercises). One of the most important points addressed is that of the **transfer of skills** from one problem-solving environment to another. I believe the activity that helped me the most was bridging the problem solving skills (which I developed during the workshops) to different worlds, technical and everyday life. I think it was writing the reflective reports that underlined this. The report made me focus on applying the learned skills." Many of our alumni now run workshops based on the MPS materials in industry.

Recruiters wished to remain anonymous. However, here are the reactions we have received:

- employer X used to recruit on 15 campuses across Canada, then on 5 and now on 3. McMaster is one of the three.
- employer Y hired a series of our graduates, each of whom he said could "think for themselves and solve problems upon graduation." He also hired from two other ChE schools in Canada, and noted that they had to spend "1 to 1 1/2 years" training the new hires before they could "think for themselves."
- employer Z requested that another university should set up identified parts of our MPS problem solving program before they would recruit from their campus;
- employers O, P, Q, R, S and T who hired us or graduates of our program to give in-house MPS workshops on problem solving.
- employer M comments "graduates of the McMaster ChE program are able to clearly communicate ideas. I see vast and immediate differences between graduates of the McMaster program and other university science programs."

The alumni, recruiter and employer responses are difficult to interpret because our program includes many elements. Yet, employers identify the problem solving and group process skill as a clearly identifiable attributes that they see our graduates possess. Identifying which components in our whole program created this shift, and the role of PBL, is impossible for us to discern.

Alumni donations have been designated to extend and further develop the MPS program.

2.3-8: Student and Faculty Acceptance: Sophomore students initially have trouble understanding and accepting courses in "soft" skills. Once they are through the first course, acceptance is high. Indeed, they will anecdotally report about how the 2G2 [course #1] helped them with their summer employment. To allay their fears and gain early acceptance of the courses, we invited alumni and recruiters to come to the first classes and give testimonials. This has worked very well.

Initially, some colleagues within the Department allowed the MPS program to proceed. Now most have become active supporters as they have gained a better understanding of the program and have seen the evidence of its effectiveness. Indeed, the evaluation of the program is vital to gain support from more and more faculty. Within the other branches of engineering, understanding

Table 1: List of the MPS Units

Core Units for course #1

1. Awareness
2. What is Problem Solving?
3. Self-assessment
4. Strategies
5. I want to and I can: Stress Management
6. Analysis: classification
7. Creativity
8. Introduction to visual thinking: translation
9. Define the stated problem
10. Getting Unstuck
11. Identifying Personal Preference and Implications
12. Learning Skills
13. Analysis: Consistency
14. Creating the Look Back and Extending Experiences
15. Exploring the Situation to Identify the Real Problem
16. Tactics:
17. Time Management for Individuals
18. Evaluation and Stress Management.

Core Units for course #2:
No new units introduced. Application of skills developed in course #1.

Core Units for course #3

19. More on Visual Thinking: Reading P&IDs
20. Asking Questions
21. Analysis: Sequences and Series
22. Broadening Perspectives.
23. Obtaining Criteria.
24. Decision making.

23-24a. Criteria and Decision making in the context of career Counselling and Guidance.

25. Time Management for groups and projects.
26. Listening and Responding:
    a) Attending and following
    b) Body language.
    c) Reflecting
27. Group Skills.
28. Group Evaluation.

Core Units for course #4

29. Being an Effective Chairperson
30. Analysis: Reasoning and Drawing Conclusions
31. Defining Real Problems
32. Implementing
33. Coping with Ambiguity:
34. Trouble Shooting
35. Heuristics or Rules-of-thumb for Problem Solving:
36. Self-Directed Learning: or Problem-based Learning
37. Simplifying and Generalizing:
38. Consolidating the Knowledge Structure:

38a. Consolidating the Knowledge Structure in Chemical Engineering:

39. Creating Tacit Information or Experience Knowledge:

39a. Creating Tacit Information or Experience Knowledge in Chemical Engineering:

40. Successive Approximation and Optimum Sloppiness:

Other Units

41. Finding Opportunities
42. Procrastination and other Attitudes:
43. Giving and Receiving Feedback
44. Assertiveness
45. Coping Creatively with Conflict
46. Coping with Difficult Behaviours
47. Accentuating the Negative
48. Communication:
49. Coping with Change:
50. Being a Change Agent
51. Managing Change
52. Fundamentals of Interpersonal skills
53. Effective Teams and Team building
54. Goals, Mission and Vision
55. Roles and Responsibilities in Teams
56. Networking: How to enrich your Life and Get Things Done
57. Convincing Others: Getting a Buy-in
58. Leadership

Table 2: Details of the MPS units, their sequence and themes

MPS Process skill		Number of MPS Units or topics	In-class workshop time for all the units	Comments: Typical time allocation across the four, required courses.
Self-awareness, self confidence, self-management.		4 + 3: stress management, time management, the unique you, managing anger (plus *awareness, self assessment, personal enrichment)*	10 h +	In course #1, 38 h. In course #2, 18 h on the application of these skills. No new skills introduced.
Personal problem solving	well-defined problems	14 + 4: awareness, strategies, analysis (classification), analysis (consistency), creativity, drawing diagrams, engaging in the problem, defining the stated problem, getting unstuck, creating the look back, exploring the problem, tactics & heuristics, criteria, decision-making (plus *learning skills, stress management, time management, the unique you*).	45 h +	
	ill-defined problems	6: broadening perspectives; defining real problems: mission, vision & goals; trouble shooting; coping with ambiguity; optimum sloppiness & successive approximation; project management.	30 h	In course #3, 5 h. In course #4, 15 h.
Interpersonal & group skills		8 + 3: interpersonal skills, asking questions, listening, assertiveness, group skills, chairperson skills, conflict resolution, giving and receiving feedback (plus *the unique you, managing anger, stress management)*.	45 h	In course #3, 15 h. In course #4, 5 h.
Self-assessment		2: self assessment; personal enrichment	10 h + time for personal goals	From all the courses a total of about 10 h is devoted to this topic.
Change management		1 + 2: managing change (plus *stress management, managing anger).*	2 h +	In course #3, 2 h.
Lifetime learning skills		4 + 1: knowledge structure, tacit or experience knowledge, learning skills, self-directed learning/PBL (plus *the unique you).*	8 h +	In course #1, 2 h; In course #3, 2 h; In course #4, 8 h.
		Total workshop time needed if all topics included:	150 h	Total time available in the curriculum: 120 h.

and acceptance has been slow. However, within the last couple of years several colleagues have tried selected

MPS units. The very positive in-course student response has encouraged these faculty to enlarge the offerings.

2.4 Summary

The MPS program is a series of four, required, workshop-style courses to develop process skills and to use small group, self-directed PBL in tutorless groups. The target skills being developed include self-confidence, problem solving, interpersonal and group, self-assessment, change management and lifetime learning. Eight measures were used to evaluate the effectiveness of the program.

2.5 References

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the MPS program: the McMaster Problem Solving program

3. Design of an MPS Unit

In designing a learning environment for students to develop *process skills* we used the following guidelines:

M don't lecture
M don't have any time when "teacher talk" lasts more than 20 minutes
M this is not Discovery learning: this is practice to develop a skill. **Tell** them the results from research that identify the target skills and attitudes.
M use reflection and prompt feedback often throughout the activity
M start with **building** the process skill in a subject-independent domain; then move to **bridging** the skill application in your subject domain; finally, require them to reflect, to record and to provide evidence of skill **extension** to everyday life.

Each unit has thirteen elements:

1 Definition of the starting target skill. *All want a clear idea of the skill.*

2. Rationale as to why the acquisition of this skill is important for their life. *To motivate, participants want to know why this skill or attitude is important for them*

3. Brief reflective Pretest of their current awareness and skill with the target skill. *We have found it extremely important to capture the participants initial thoughts about their skill. This helps them to see progress. This helps develop their confidence. "Awareness" and "skill" are sufficient.*

4. Reading of the Learning Objectives for the unit ***The behavioural objectives are the key to skill development.*** *Behavioural objectives about the skills are needed for assessment and to develop understanding. When these are read at the beginning of the Unit, few understand the meaning. The objectives contain many jargon terms. Ask the participants to be patient. The objectives will be revisited in Step 11.*

5. Where the skill fits into the larger context. *Provide the participants with an appreciation of where this particular target skill fits into the overall skill. For example, where does "creativity" fit into the skill of "problem solving"? Concept maps showing these for "problem solving" are given on p 3-2 of "Problem-based L:earning: how to gain the most from PBL," HTGTM; for "group skills" on p. 5-2 of HTGTM; and for "lifetime learning skills, p. 7-2 of HTGTM.*

6. The Route ahead for the Unit workshop. *This lists the activities in the rest of the workshop. This provides the advanced organizers.*

7. **Building** activities with feedback and reflection. *The participants now do activities and receive prompt feedback about their performance. After each activity, participants should reflect on what they learned from the way they performed the skill. We try to select a context that is known by all.*

8. Teacher summarizes research about how successful people use and apply the target skills. *Once the participants have sampled the skill and received feedback, we now draw on the "novice" versus "expert" research evidence to describe the performance of the expert or successful person.*

9. **Bridging** activities with feedback and reflection. *Now participants are given opportunities to repeat the skill and incorporate and internalize the "expert" behaviour in their subject domain. Throughout participants reflect.*

10. Brief reflective Posttest of awareness and skill. *This is a revisit of activity #3. Now that the Unit is almost complete participants reflect on how they have changed in awareness and skill.*

11. Check that the Objectives have been achieved. *In Activity #4, we considered the learning objectives for the Unit. Here these are revisited. Participants use evidence collected from the workshop to rate the degree to which they have achieved the Objectives.*

12. DISCOVERY. The teacher can either summarize the Unit or can ask participants to list what they have discovered and how they will apply that information/skill. *I enjoy having the participants summarize. This may take*

longer, but it provides feedback to us about the main ideas they experienced.

13. **Extend** Require the participants to keep a daily journal describing evidence of when they applied the skill in other situations and in everyday life. The journal should focus on the skills from the current Unit; however, the application of previously acquired skilled should also be included. This elaboration helps develop confidence and integrate the skills. *We require that these data are documented and handed in one week after the workshop is complete. Sample format for the journal are given in "Problem-based Learning: resources to gain the most from PBL," Chapter A; Chapter F gives examples of the journals.*

the MPS program: the McMaster Problem Solving program

4. Details of Units

I have tried to give background, objectives, timing sheets and transparencies for the Units as I complete the documentation. You may use these in your context. I would appreciate your acknowledging the source.

1. Awareness
    - Background
    - Objectives
    - Timing sheets
    - Transparencies
    - More
2. What is Problem Solving?
    - Background
    - Objectives
    - Timing sheets
    - Transparencies
    - More
3. Self-assessment
    - Background
    - Objectives
    - Timing sheets
    - Transparencies
    - More
4. Strategies
    - Background
    - Objectives
    - Timing sheets
    - Transparencies
    - More
5. I want to and I can: Stress Management
    - Background
    - Objectives
    - Timing sheets
    - Transparencies
    - More
6. Analysis: classification
    - Background
    - Objectives
    - Timing sheets
    - Transparencies

- Objectives
- Timing sheets
- Transparencies
- More

16. Tactics:
    - Background
    - Objectives
    - Timing sheets
    - Transparencies
    - More
17. Time Management for Individuals
    - Background
    - Objectives
    - Timing sheets
    - Transparencies
    - More
18. Evaluation and Stress Management.
    - Background
    - Objectives
    - Timing sheets
    - Transparencies
    - More
19. More on Visual Thinking: Reading P&IDs
    - Background
    - Objectives
    - Timing sheets
    - Transparencies
    - More
20. Asking Questions
    - Background
    - Objectives
    - Timing sheets
    - Transparencies
    - More
21. Analysis: Sequences and Series
    - Background
    - Objectives
    - Timing sheets
    - Transparencies
    - More
22. Broadening Perspectives
    - Background
    - Objectives
    - Timing sheets
    - Transparencies
    - More.
23. Obtaining Criteria.
    - Background
    - Objectives
    - Timing sheets
    - Transparencies

- Background
- Objectives
- Timing sheets
- Transparencies
- More

30. Analysis: Reasoning and Drawing Conclusions
    - Background
    - Objectives
    - Timing sheets
    - Transparencies
    - More
31. Defining Real Problems
    - Background
    - Objectives
    - Timing sheets
    - Transparencies
    - More
32. Implementing
    - Background
    - Objectives
    - Timing sheets
    - Transparencies
    - More
33. Coping with Ambiguity:
    - Background
    - Objectives
    - Timing sheets
    - Transparencies
    - More
34. Trouble Shooting
    - Background
    - Objectives
    - Timing sheets
    - Transparencies
    - More
35. Heuristics or Rules-of-thumb for Problem Solving:
    - Background
    - Objectives
    - Timing sheets
    - Transparencies
    - More
36. Self-Directed Learning: or Problem-based Learning
    - Background
    - Objectives
    - Timing sheets
    - Transparencies
    - More
37. Simplifying and Generalizing:
    - Background
    - Objectives
    - Timing sheets