Assessment of Pharmacy Students' Critical Thinking and Problem-Solving Abilities[1]

Barbara Adamcik, Steve Hurley and John Erramouspe

College of Pharmacy, Idaho State University, Campus Box 8288 Pocatello ID 83209-8288

Pharmacists must be competent in detecting and resolving drug-related problems to effectively provide pharmaceutical care. Little is known, however, about students' problem-solving processes or their relationship to clinical decision-making. This paper reports the findings from 40 clerkship students who completed a computer program (CAP) developed to assess problem-solving skills, as well as various instruments to assess cognitive and learning styles as they relate to clinical decision-making. In addition, preceptors' evaluations of students' problem-solving skills were collected. Findings revealed similarities among students in temperament, learning styles, information-processing modes, problem-solving strategies, and critical-thinking strengths. Correlations of overall and individual problem-set CAP scores with the other instruments were weak. Although further study is needed, the cognitive instruments present a profile of pharmacy students which may be useful in modifying didactic, laboratory, and experiential components of pharmacy education to improve students' abilities to identify and resolve clinical problems.

INTRODUCTION

The AACP Commission to Implement Change in Pharmaceutic Education states in Background Paper I that the mission of pharmacy practice is to deliver pharmaceutical care(1). An important objective of pharmaceutical care is to achieve desired patient outcomes by "preventing, identifying, and resolving drug-related problems in patients" using "clinical reasoning and expert decision making." It is apparent that significant interest exists among pharmacy educators and practitioners in understanding and developing critical thinking and problem-solving as professional competencies(2).

A review of the medical and educational literature reveals several theoretical models of problem-solving. As expected, it is reported that intelligence tests measure some problem-solving abilities(3). However, the way(s) a person learns, and the reasoning and problem-solving processes used, are highly interrelated and difficult to measure separately(4).

Information on how medical practitioners solve problems has grown considerably, and the classic theory presented is one of hypothesis-oriented inquiry, which consists of approximately six to eight steps, depending on the model being discussed (3,5-9). In the context of pharmaceutical care, the process likely involves the following steps:

1. recognize the existence of a drug-related problem or problems, and identify relevant or problematic issues;
2. gather both general and specific patient-, disease-, and drug-related information to define further the nature of the patient's problem(s).
3. rank the patient's drug-related problems and define goals and desired outcomes for each;
4. generate ideas, hypotheses, and potential solutions; evaluate each in relation to the identified problem(s);

and select the most plausible hypotheses or solutions;

5. plan the actions to be taken; gain acceptance of the plan by the patient and other individuals involved in the patient's care; and allocate available resources to reach the desired outcomes; and

6. take the planned action, monitor the results of the action(s) taken, and determine if further actions need to be taken; this may involve repeating earlier steps or the entire process again.

Little is known about how personality and cognitive factors, critical thinking and problem-solving abilities, and academic performance are related. This paper reports on a preliminary exploration of the relationships among these variables and with data from an interactive computer program developed to assess problem-solving. Using scores from the computer assessment program and the Watson-Glasser Critical Thinking Assessment Instrument as dependent variables, the effects of the independent variables included in this study were examined. In addition to gender, grade point average and mean therapeutics points, several paper-and-pencil instruments were included as variables in this study and are described below.

INSTRUMENTS USED IN THIS STUDY

An interactive computer program was developed by the authors using the TenCORE Authoring System on an IBM-compatible computer(10). Early versions of the program were tested with faculty, pharmacists, and third-year (P3) pharmacy students, and the program was revised several times to eliminate problems related to clarity, delivery, content and function.

In addition, other instruments and sources of data were included in this study to assess problem-solving attributes and to validate the computer assessment program. These included inventories to assess: critical thinking abilities, learning styles, information-processing styles, problem-solving profiles, as well as students' pharmacy grade-point averages and mean points received in a two-course (four credits each) therapeutics sequence. A brief description of each instrument follows.

Computer Assessment Program (CAP). This interactive program contains four distinct problem-sets developed to evaluate different aspects involved in critical thinking. Each problem-set is scored separately and a cumulative, total score is computed as well.

Problem-Set 1, the "Heart" problem, incorporates a physiological animation of the cardiovascular system. The student is required to identify the actions of three different hypothetical drugs, presented singularly first, and then in combinations, and the direct and indirect effects of each on heart rate and vascular tone. As each drug or combination is administered, the animation presents a visual representation of the actions of the drug. Students answer 10 questions as they progress through the program. *Problem-Set 2, the "Terpitis" clinical case,* involves a hypothetical infectious disease (terpitis) and two fictitious antimicrobials. The student is provided with on-screen drug information and pertinent but limited subjective and objective patient data. The student must initiate treatment with the best drug, at a proper dose, and then monitor and respond to the patient's daily progress, making changes in drug therapy as necessary. *Problem-Set 3, the "Otitis Media" module,* is a straight-forward tutorial on the treatment of otitis media. The module presents a case with textual information on the disease state and therapeutic principles for use of antimicrobials. *Problem-Set 4, "Puzzles"* includes seven biomedical problems or puzzles, which involve mathematical deduction, tricky wording, brain-teasers with irrelevant information, and/or drug information-searching problems.

The software program records whether a student completes each problem-set, the number of correct responses for each problem-set and a total score (maximum - 37). The time (in minutes) students are logged onto the program is also recorded, and is used as a surrogate measure of how long it takes students to complete the program.

Watson-Glaser Critical Thinking Appraisal Inventory (CTAI). The CTAI is composed of five subtests which assess relevant attitudes, knowledge and skills related to critical thinking(11). Each subtest presents 16 test items, and the maximum total score is 80. The subtests assess different aspects of critical thinking: *Test 1, Inference,* measures the ability to determine the degree to which a limited amount of information presented in a problem supports the conclusions drawn. *Test 2, Recognition of Assumptions,* assesses if respondents can determine whether a conclusion presented uses unstated assumptions or information. *Test3, Deduction,* assesses respondents' ability to recognize when a conclusion necessarily "follows" or "does not follow" from a combination of two premises presented. *Test 4,Interpretation,*evaluates how well respondents can weight evidence and decide if generalizations or conclusions based on the information provided are warranted. Finally, *Test5, Evaluation of Arguments,* measures how well respondents can distinguish in the problems presented, between arguments that are strong and relevant, and arguments that are weak or irrelevant.

A review of the literature did not reveal any pharmacy-related studies using the Watson-Glaser CTAI. Non-pharmacy experience with this instrument has produced data on norms, reliability, validity and comparability with measures of academic achievement(11). Construct validity was established by significant correlations with the Scholastic Aptitude Test (SAT) ($P<0.05$), and the American College Testing (ACT) Program ($P<0.01$). The CTAI does not correlate significantly with high school or college freshman grade point averages, however. In addition, even though the CTAI correlates with the Weehsler Adult Intelligence Scale and the Otis Mental Ability Tests, factor analysis has shown that the CTAI is measuring a dimension of ability that is only a component of overall intellectual capacity(11).

Among nursing students, Miller found that performance on the CTAI improved following completion of a baccalaureate RN program(12). The CTAI had a weak but significant correlation with nursing grade point average ($P<0.05$), but not with the non-nursing aspects of overall grade point average.

Creative Problem-Solving Profile (CPSP). The CPSP was developed by Basadur and associates to identify preferred problem-solving styles(8,13). The CPSP is oriented around an eight-step circular model of the creative problem-solving process which includes: *Step I, Problem finding,* anticipating future problems and seeking out current problems; *Step 2, Fact finding,* problem-related information seeking; *Step 3, Problem definition,* clarification of the problem; *Step 4, Idea finding,* generating potential solutions; *Step 5, Selecting and evaluating potential solutions; Step 6, Planning for action to be taken; Step 7, Gaining acceptance of the planned action;* and *Step 8, Taking planned action* (Fig. 1).

This eight-stage process is repeated as needed, and at each stage, both divergent thinking (idea generation) and convergent thinking (idea evaluation) are required for optimal solution of problems. As seen in Figure 1, there are two opposing bipolar dimensions indicating: (i) a preference for gaining knowledge (learning) by direct, concrete, experiencing (BE), or by abstract, detached, thinking (BT); and (ii) a preference for using knowledge for ideation (divergent thinking) (FI), or for evaluation (convergent thinking) (FE). Basadur proposes that people vary considerably in which phases of the eight-step circular problem-solving process they prefer working. Thus, each quadrant is labelled to indicate a preferred problem-solving style and steps in the problem-solving process. *Generators prefer* working on problem-sensing and fact-finding (Steps 1 and 2), and are good at getting things started, comfortable with ambiguity, and capable of handling a great deal of information. *Conceptualizers* are most comfortable with Steps 3 and 4, definition of the problem and fact finding. They are described as able to integrate seemingly unrelated information into hypotheses, theories, and the big picture; and as good problem definers and idea developers. *Optimizers* are described as good problem solvers, and prefer working on Steps 5 and 6 of the process. Finally, *Implementors* are the problem finishers. They work best on the final two steps in the process, and are viewed as less concerned with understanding the theory behind a new idea or plan, and more concerned with getting it up and running.

The Basadur instrument is relatively new and has not been used with pharmacy students. It was used, however, by Fink[2] in her PhD dissertation research with 269 college students to investigate the effects of a creative attitude, openness, and motivation on creative thinking. Basadur reports data on face and construct validity from a study with 181 undergraduate business students(8). This instrument was selected for this study because it identifies the characteristic ways students solve problems (not how well they are solved) and it directly relates to the major aspects involved in clinical problem-solving and decision making. In addition, findings from this aspect of the study may provide insight to pharmacy students' preferred steps in the cyclic problem-solving model. This in turn may result in better methods for teaching pharmacy students about the whole problem-solving process, and the value of both divergent and convergent thinking at each step.

Learning Styles Inventory (LSI). The LSI was developed by Kolb(14-16) and is based on theoretical work by Piaget and Guilford related to intelligence, thinking, and creativity. The learning styles model is similar in structure to Basadur's creative problem-solving model, although it emphasizes how learners absorb and deal with new information (Fig. 2).

The LSI instrument assesses four preferred ways of learning: from feelings (CE), by watching and listening (RO), by thinking (AC), and by doing (AE). Preference scores are mapped on two bipolar axes to determine a respondent's preferred leaning style. *Divergers* demonstrate a preference for learning from feelings and by watching, and are considered as being best at viewing concrete situations from many different points of view and at generating a wide range of ideas. *Assimilators* are viewed as being able to understand a wide range of information and to put it into a
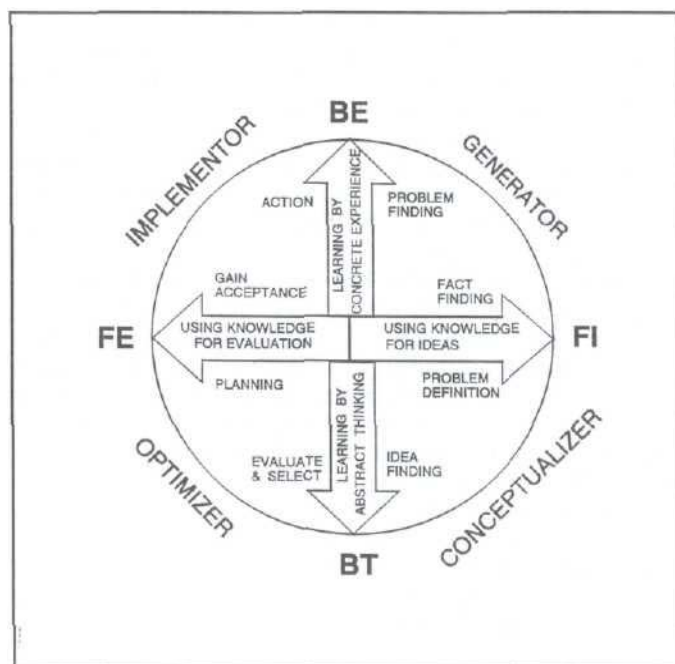

Fig. 1. *Creative Problem-solving Model (adapted from Basadur and Finkbeiner (ref. 13]).*

concise, logical format. Assimilators are reported to find it more important that a theory has logical soundness than practical value. The *Accommodators* learn primarily from hands-on activities and enjoy carrying out plans and being involved in new and challenging experiences. Finally, the *Convergers,* who prefer leaning by thinking and doing, are considered best at finding practical applications for ideas and theories, and are described as being good at solving problems and making decisions based on finding solutions.

In one study using the LSI with pharmacy students, 49 percent of students were found to prefer learning by thinking and doing (Converger learning style), 19 percent were Assimilators, 19 percent were Accommodators, and 13 percent were Divergers(17). This distribution is similar to that found for practicing pharmacists, physicians, nurses, and adults with an undergraduate college degree (17,18). Garvey and colleagues reported that pharmacy students labelled as convergers had a significantly higher pharmacy grade point average compared to the other three learning styles(17)

Creative Styles Inventory (CSI). The CSI distinguishes between two modes of information-processing (thinking) which are posited to affect learning, making decisions, and solving problems(19-21). The Logical Mode of information-processing is left-brain oriented, and is associated with strengths in logical, analytical, verbal and highly structured ways of thinking. These individuals are characterized as being rational, able to make objective judgments, prone to focus on differences, responsive to environmental structure and changes, and able to see cause and effect. The Intuitive Mode is right-brain oriented and is associated with a preference for intuition, synthesis, spontaneity, and thinking with patterns and images. Individuals dominant in this mode are described as problem-solvers with hunches; able to discern patterns, make subjective judgments, perceive similarities, detect correspondences and resemblances, and able to take a meta perspective of a situation or problem. Individuals who are considered to be Balanced between these two modes, with neither mode appearing to be dominant, tend to

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[2]Fink, M. and Adamcik, B., "Effects of creative attitude, openness, and motivation on creative thinking," unpublished data (1993).
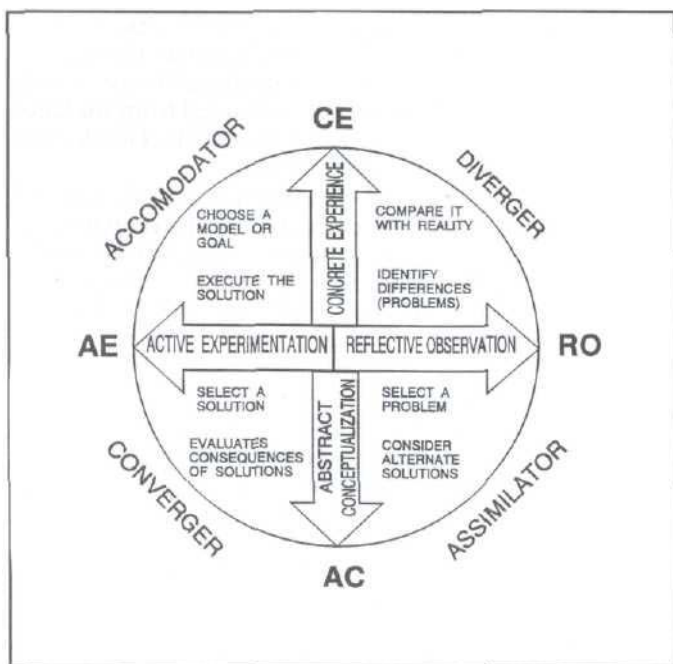
Fig. 2. Learning Styles Model (adapted from Kolb [ref. 15J).

move between modes in different situations.

Both the LSI and the CSI are available in a commercial package known as 4MAT(22). This product is marketed as a way to help teachers use multiple modes of instruction to improve student motivation, retention, critical thinking and academic achievement. Knowledge of these student preferences and styles would be valuable in redesigning courses to maximize learning.

Myers-Briggs Personality Types. The Myers-Briggs Type Indicator (MBTI) has been used frequently with pharmacy students(23-28). This instrument is based on Carl Jung's comprehensive theory of psychological types. The MBTI scores locate each respondent on four bipolar interpersonal dimensions: introversion-extroversion, sensing-intuition, thinking-feeling, and judging-perceiving. There are 16 personality types which derive from these four dimensions. Because the MBTI has been used extensively with pharmacy students, the characteristics associated with the four bipolar dimensions will not be described here.

Keirsey and Bates(29) discuss four temperaments related to the MBTI dimensions. The two most common patterns (each representing 38 percent of the population) are the SJs (sensing + judging) and the SPs (sensing + perceiving). The SJs are depicted as concerned about being prepared, very responsible, are often caregivers, and exemplify the ideals of the work ethic. In contrast, the SPs are seen as action and here-and-now oriented, spontaneous and impulsive, process oriented, and as working best in a crisis situation. The remaining two temperaments, NTs and NFs, each represent about 12 percent of the population. The NTs (intuitive + thinking) are characterized by a desire to be able to understand, control, predict, and explain realities. They are the scientists of the world, and are the most self-critical of all the temperaments, continually seeking competence in many forms. The NFs (intuitive + feeling) demonstrate a continuous interest in search for self and meaning in life; they are extremely sensitive to subtleties in gestures and

metaphoric behavior not always visible to other personality types. They generally have excellent people skills.

Although the MBTI has been used a great deal with pharmacy students, and is administered to all applicants to our pharmacy program who are interviewed, no investigations were found which relate the MBTI dimensions, personality types, or temperaments to the various aspects and components of problem-solving and critical thinking. Generally, the MBTI has been used to characterize pharmacy students and evaluate objective outcomes in pharmacy school programs. Data on 2,433 pharmacy students in Illinois and Florida reported that 52 percent of students were dominant on the introversion dimension, 56 percent as sensing, 53 percent as feeling, and 59 percent as judging(17). Women pharmacy students and faculty are reported to be somewhat more extroverted and feeling compared to their male counterparls(26,27).

Gordon Lawrence, in his book, *People Types and Tiger Stripes,* presents a very practical discussion of the relationship between learning styles and personality types(30). For example, he describes sensing types as being linear learners who prefer the step-by-step approach to learning a task. On the other hand, intuitive types are global learners who prefer to see the whole task first. His discussion of strengths and weaknesses associated with various learning strategies is helpful in understanding the different learning strategies and needs of students we find in the pharmacy classroom, lab and clerkship environments.

Lowenthal and Meth found that judging scores correlated significantly with final pharmacy grade point average(28). They reported that women with dominance in the extrovert, intuitive, thinking and judging dimensions, and males dominant in the introvert, intuitive, feeling and judging dimensions had better overall academic performance on several measures (*e.g.,* SAT, PCAT, GPA, and NAPLEX). Rezler reported that higher introvert and judging scores were associated with a higher GPA (75 percent of students in his study were male)(24). He also found a weak interaction between the MBTI dimensions and gender which predicted career choices (e.g., hospital pharmacy vs. retail chain pharmacy)(25). Determination of which characteristics are most compatible with the practice of pharmaceutical care will require further study.

RESEARCH QUESTIONS AND HYPOTHESES

Based on the literature review, the following research questions were developed to guide evaluation of the computer assessment program (CAP) and to focus the assessment of student characteristics that may be associated with effective problem-solving attributes or skills.

1. How do scores on the CAP compare with scores on the Watson-Glaser CTAI?
2. Are there significant differences by gender on these two dependent variables?
3. Are there significant differences by measures of students' academic performance (pharmacy GPA and/or average Therapeutics points) on the two dependent variables?
4. Are there significant differences by personality types or temperaments, or by learning, information-processing, and problem-solving styles on the two dependent variables?
5. How well do preceptors' evaluations of students' clinical problem-solving abilities correlate with the two

dependent variables?

6. Are there a subset of the variables in this study which adequately predict students' scores on the CAP or the CTAI?

The hypotheses developed from the literature review and research questions, and tested with the data are:

H_1 There is a significant positive association between students' scores on the CAP and CTAI.

H_2 There are no significant differences between students' scores on the CAP or CTAI by gender.

H_3 There is a significant positive association between students' scores on the CAP and CTAI, and pharmacy GPA and average Therapeutics points.

H_4 There are no significant differences between students' scores on the CAP and CTAI by: temperament (MBTI), preferred learning style (LSI), preferred information-processing style (CSI), or preferred problem-solving style (Basadur CPSP).

H_5 There is a significant positive association between preceptors' evaluations of students' clinical problem-solving abilities and scores on the CAP and CTAI.

H_6 A subset of the variables in this study adequately predict students' scores on the CAP and CTAI.

METHODS AND PROCEDURES

Participants

The subject pool included all P4 clerkship students (final year of PharmD program) during the Spring semester, 1992 (Cohort 1, n = 38), and all P4 clerkship students during the Summer, 1992 (Cohort 2, n = 40). Clerkship students were asked to participate, but were not required to do so, and participation or nonparticipation was not related in any way to the student's final evaluation on a rotation. Some students were unable to participate because they were off rotation during the period data was collected. Cohort 2 was recruited in order to increase the size of the sample. Cohort 1. students were recruited during rotation 10 (10th out of 11 rotations); Cohort 2 students were recruited during rotation 2. Therefore, Cohort 1 students were nearly finished with the final year of the program, and Cohort 2 students were just beginning the final year. Initially, data from the two cohorts of students were analyzed separately and, finding no significant differences by gender, grade point average, or mean therapeutics points, the data were then combined into one database.

Procedures

Packets were mailed to students at their clerkship sites (at beginning of rotation 10 or rotation 2) and contained the assessment instruments (CTAI, CPSP, LSI, CSI, and MBTI), the computer assessment program (CAP), and instructions. Students were asked to complete the computer program and other materials during the 3rd or 4th (final) week of the rotation, and to mail them back in an enclosed postage paid envelope at the end of the last week of that rotation. Efforts were made to remind students to return their packets by a phone call to the preceptor and to the student. Data were received on a total of 66 students (35 from Cohort 1, 31 from Cohort 2). However, for 26 students sufficient data was missing *(i.e.,* assessment instruments, CAP, CTAI, or preceptor's evaluation) and they were omitted from the analyses. For Cohort 1, packets were sent to 38 P4 students, and 19 completed packets were returned (50 percent response rate). For Cohort 2, packets were sent to 40 P4

students, and 21 were returned (53 percent response rate).

Students' pharmacy GPAs (for all courses through the P3 year) and mean therapeutics points (from two four-credit courses taken in the P3 year) were obtained from students' files and therapeutics test scores respectively. Gender was added to the database for each student.

A total of 40 students completed the study packets; however, not all students completed all instruments correctly, so the totals for some instruments may be less than 40. There were 25 female students and 15 male students in the study (Cohort 1: 11 females, eight males; Cohort 2: 14 females, seven males).

Preceptors' Evaluations

Preceptors at each clerkship site were asked to evaluate their students on abilities related to clinical problem-solving. The one-page instrument contained one question which assessed overall clinical problem-solving, and nine questions which assessed specific aspects of clinical problem-solving (Appendix A). There were minor differences in the procedures followed for preceptors' evaluations of students in the two cohorts. For Cohort 1 students there were multiple evaluations by their preceptors on rotations 9, 10 and 11. Evaluations by preceptors on rotations 9 and 10 were conducted prior to completion of the packets by the students; therefore, the preceptors were not certain what kinds of data would be collected. Preceptors evaluating students on rotation 11 (Cohort 1) and the summer rotation (Cohort 2) were aware of what the instruments were assessing, which may have increased the potential for bias in these evaluations.

All data were enter into a database and analyzed using the Statistical Package for the Social Sciences (SPSSx). Casewise deletion was used for all analyses to ensure that students with data on the relevant variables under analysis were included. Means and standard deviations and a correlation matrix were calculated for all interval-level variables. Hypotheses were tested with appropriate statistical analyses. The P value was set at 0.05. Reliability coefficients for the CAP were computed for problem-sets 1,3, and 4 (only a total score was recorded for problem-set 2).

FINDINGS

Data from the two cohorts of students were combined as there were few significant differences between the two groups on the measures of interest in this study. The second cohort of students, however, spent less time logged onto the computer compared to the first group (49.4±21.4 vs. 71.6±28.1 minutes, $P<0.009$), scored higher on problem-set 2 (9.3±4.1 vs. 5.9±5.1, $P<0.03$), had a higher total CAP score (23.3+6.0 vs. 17.8±6.4, $P<0.01$), and included a higher proportion of MBTI sensing types (52 vs. 47 percent, $P<0.01$). These differences were not considered to be of practical importance in the validation of the CAP or hypothesis testing.

Examination of students' performance on the CAP reveals considerable variation in the amount of time the students spent working on the computer program (range = 8 to 149 minutes). Although students were expected to complete the program in one sitting, this may not have been the case, particularly for students in Cohort 1, who have increased patient-care responsibilities compared to students in the early rotations (i.e., Cohort 2). The program recorded the time logged onto the program for the last session (if there were more than one) in which the student completed

Table I. Percent student distributions on the CPSP, LSI, and CSI

| | Percent | | |
	All students	Men	Women
Problem-Solving Profile (n=37):			
Generators	19	23	17
Conceptualizes	8	15	4
Optimizers	43	31	50
Implementors	30	31	29
Learning Styles (n=24):			
Divergers	8	25	0
Assimilators	25	12.5	31
Convergers	54	50	56
Accommodators	12.5	12.5	12.5
Creative Styles (n=3S):			
Logical/Analytical	58	47	65
Balanced	24	27	22
Intuitive	18	27	13

the program; this may not be the most accurate way to determine time required to complete the program. The mean time of 59.9±26.9 minutes and the median time of 62.5 minutes correspond to the estimated time (from the pilot tests) of 60 minutes to work through the four problem-sets.

The total CAP scores ranged from eight to 36 (maximum possible was 37), with a mean score of 20.6 (which represents approximately 56 percent correct answers). Mean scores on the four problem-sets were: heart problem-set, 6.45±2.23 (10 questions); "terpitis" problem-Set, 7.7±4.8 (15 questions); otitis problem-set, 3.6±1.0 (five questions); and puzzles problem-set, 2.9+1.4 (7 questions). The standardized reliability coefficients for problem-set 1, problem-set 3, and problem-set 4 were 0.71, 0.07, and 0.34 respectively. Only problem-set 1, the heart problem, demonstrated internal consistency/reliability. The otitis problem (problem-set 3) was not internally consistent and this lack of reliability would be expected to result in lack of association of these scores with other variables in the study (31). Summary scores were used in the analyses for both problem-sets 3 and 4, however, as this was an a priori decision. Of interest is the finding that more students were able to answer correctly questions from the otitis problem-set, and the mean score represents approximately 73 percent correct. The puzzles problem-set was found to be significantly correlated with several subtest scores on the CTAI. Correlations between the individual items in each problem-set and with the other measures in the study have been examined and will be helpful in further modification of the CAP (although these data are not reported here).

Results from the Watson-Glaser CTAI reveal an overall mean score of 58.3±9.9 (which represents an average of approximately 73 percent correct). For the five subtests (with a maximum of 16 points each), the mean scores were: Inference, 8.95±2.48; Assumptions, 12.15±3.33; Deduction, 11.80±2.05; Interpretation, 13.10±2.24; and Arguments, 12.28±2.60.

Students' distributions on the Basadur CPSP, LSI and CSI are presented in Table I. Nearly three-quarters of the students were identified as convergent thinkers (idea evaluation) on the Basadur Inventory; these are the Optimizers,

who learn by abstract thinking, and the Implementors, who learn by experience. The same pattern was noted for both men and women students. On the LSI, over half of the pharmacy students demonstrated a preference for the Converger style of learning, which involves both abstract conceptualization and active experimentation. Finally, the majority of students showed a preference for the logical/analytical style of information-processing on the CSI. There were no significant differences by cohort or gender on these three inventories. The small number of respondents in this study makes it difficult to determine the significance of these distribution patterns for pharmacy students. However, these instruments and the CTAI were used with first-year (PI) students (n=53) in the Fall semester, 1994, and the results obtained were very similar to those of the P4 students in this study. Specifically, PI student data revealed a mean total score on the CTAI of 60.56±8.16; 71 percent of the students were convergent thinkers (optimizers and implementors on the Basadur CPSP), and 60 percent were logical/analytical on the CSI. The only difference noted between the two groups of students (P4s and P1s) was in dominant learning styles. Twenty-five percent of the P4 students were Assimilators, whereas 58 percent of the PI students were Assimilators; 54 percent of the P4 students were Convergers, compared to 29 percent of the PI students.

Results from the Myers-Briggs Type Indicator reveal a majority of students showing a preference for being introverted (56 percent), sensing (64 percent), thinking (56 percent), and judging (74 percent). These percentages are consistent with other studies of pharmacy students. The dominant temperament was sensing-judging (51 percent SJs). Ten percent of students were identified as SPs, 16 percent were NTs, and 23 percent were NFs. There were no significant differences by cohort or gender, although the pattern was strongest for women (64 percent were SJs, and 20 percent were NFs) compared to men (SJs, NTs, and NFs were each 29 percent). This pattern may reflect a change in the types of students attracted to or accepted into our program; however, more data is needed before this hypothesis can be tested. Data from the 1994 PI student cohort revealed 62 percent were SJs, 15 percent were NTs, 21 percent were NFs, and two percent were SPs.

Correlation matrices were generated for the CAP and the Watson-GIaser CTAI. For the CAP, scores on the heart problem were significantly correlated with both the "terpitis" (r = 0.27, $P<0.05$) and puzzles (r = 0.32, $P<0.025$) problem-set scores. The "terpitis" and puzzles scores also were significantly correlated (r = 0.31, $P<0.03$). One interesting finding is a significant negative correlation between total time to complete the program (time logged on) and two of the problem-sets and the total score. The data indicate that students who took less time working through the computer program scored significantly higher on the heart (r - -0.38, $P<0.009$) and puzzles (r = -0.41, $P<0.006$) problem-sets and on overall total score (r = -0.34, $P<0.019$). As expected, all of the separate subtests of the Watson-Glaser CTAI were significantly intercorrelated.

A correlation matrix of CAP scores with CTAI scores was generated to test the first hypothesis, that there is a positive association between students' scores on both dependent measures. The Watson-Glaser CTAI Inference subtest was positively correlated with scores on the otitis (r=0.30, $P<0.035$) and puzzles (r=0.37, $P<0.009$) problem-sets and the total CAP score (r=0.29 $P<0.038$). The Deduc-

Table II. Correlation of academic performance and scores on the CAP and CTAI

	Pharmacy GPA r =	Therapeutics Points r =
Pharmacy GPA:		0.74[c]
Computer Program		
Set 1: Heart	-0.03	0.01
Set 2: Terpitis	0.24	0.40[a]
Set 3: Otitis	0.01	-0.08
Set 4: Puzzles	0.29[a]	0.21
CAP Total Score	0.26	0.36[a]
CTAI Subtests		
1: Inference	0.45[b]	0.30[a]
2: Assumptions	0.40[a]	0.32[a]
3: Deduction	0.57[c]	0.66[c]
4: Interpretation	0.62[c]	0.45[b]
5: Arguments	0.52[c]	0.37[a]
CTAI Total Score	0.64[c]	0.52[c]

[a]$P<0.05$.

[b]$P<0.005$.

[c]$P<0.0001$.

Table III. Correlation of preceptor's evaluations and scores on the CAP and CTAI.

	Cohort 1 Global* r =	(rot 10) Specific r =	Cohort 2 Global r =	(rot 2) Specific r =
Computer Program				
Time (minutes):	0.17	0.05	-0.01	-0.06
Set 1: Heart	0.02	0.06	-0.07	0.10
Set 2: Terpitis	0.01	-0.02	0.51[a]	0.57[b]
Set 3: Otitis	-0.50	-0.31	-0.29	-0.27
Set 4: Puzzles	0.19	0.24	0.69[a]	0.37
CAP Total score	-0.02	0.01	0.44	0.48[a]
CTAI Subtests				
1: Inference	-0.47[a]	-0.28	0.66[a]	0.29
2: Assumptions	-0.77[c]	-0.51[a]	0.27	0.34
3: Deduction	0.27	-0.13	0.65[a]	0.38[a]
4: Interpretation	-0.17	-0.14	0.38	0.33
5: Arguments	-0.69[b]	-0.47[a]	0.54[a]	0.42[a]
CTAI Total score	-0.62[b]	-0.40[a]	0.59[a]	0.44[a]
Pharmacy GPA	-0.37	-0.19	0.53[a]	0.13
Therapeutics points	-0.63[b]	-0.60[a]	0.73[a]	0.30

*Global = response lo Question 1;

Specific = mean response to Questions 2a-2i; (see Appendix A).

[a]$P<0.05$.

[b]$P<0.005$.

[c]$P<0.000.1$.

tion subtest was positively correlated with the "terpitis" (r=0.33, $P<0.023$) and puzzles (r=0.29, $P<0.05$) problem-sets scores and total score (r-0.31, $P<0.030$). The Interpretation subtest was positively correlated only with the puzzles set (r-0.39, $P<0.008$). Two of the subtests, Assumptions and Arguments, were not significantly correlated with any scores on the CAP. The CTAI total score was significantly correlated with only one problem-set, puzzles (r=0.31, $P<0.030$), and was not significantly correlated with the CAP total score. The heart problem-set did not correlate with any of the CTAI subtests or total score. The puzzles problem-set appeared to reflect the concepts which underlie the CTAI better than the other three computer problem-sets. Hypothesis 1 is not supported by the data.

Hypothesis 2 relates to differences between men and women respondents on the two dependent measures. The only significant difference noted between men and women students on the CAP was on the "terpitis" problem-set: the mean number correct for men was 5.53±4.39 and for women it was 9.09±4.69 (t=2.34, $P<0.025$). Significant differences noted between men and women on the Watson-Glaser CTAI were on the following scores: Assumptions (men: 10.73±3.22 vs. women: 13.00+3.16, $P<0.035$), Interpretations (men: 12.07±2.52 vs. women: 13.72±1.84, $P<0.022$) and Total Score (men: 53.80±9.26 vs. women: 60.96±9.45, $P<0.025$). The data support Hypothesis 2 for the CAP (no differences by gender were noted) and do not support the hypothesis for the Watson-Glaser CTAI (differences by gender were noted).

Hypothesis 3 is concerned with the relationship of academic performance (pharmacy GPA and mean Therapeutics points) to scores on the two dependent measures (Table II). The mean pharmacy GPA for respondents was 3.21±0.44 (range: 2.53 to 4.00). The pharmacy GPA of women was significantly higher than that of men (3.32±0.47 vs. 3.02±0.32, $P<0.042$). The mean points for the therapeutics sequence was 77.4+7.77 percent (range: 60.2 percent to 91.8 percent). Although women scored higher than men (79 percent vs. 75 percent), the difference by gender was not significant. As would be expected, pharmacy GPA and average therapeutics points are highly correlated (r = 0.74, $P<0.0001$). Phar-

macy GPA is significantly correlated with only one CAP problem-set, puzzles. Pharmacy GPA is significantly correlated with all subtest scores and total score of the Watson-Glaser CTAI. The first aspect of Hypothesis 3 related to GPA is rejected for the CAP and accepted for the CTAI. Mean Therapeutics points is positively correlated with the terpitis problem-set and total CAP scores, partially supporting this aspect of Hypothesis 3. Finally, mean Therapeutics points is significantly correlated with the CTAI subtests and total score, lending strong support to this aspect of Hypothesis 3.

Analyses of variance revealed no differences in mean scores on the CAP and CTAI by MBTI temperament types, preferred learning styles, preferred information-processing modes, or Basadur's creative problem-solving profiles; thus the data support Hypothesis 4 (all calculated ANOVAs were not significant). The small number of students in this study and the small number of respondents in the minority categories, make it difficult to determine if these independent variables might be of significance if data from a larger sample of students were obtained.

Hypothesis 5 relates to the association of students' scores on the dependent measures and the evaluations by their clinical preceptors. Table III presents data from the evaluation instrument for question 1 (global assessment) and the mean for questions 2a to2i (specific assessments) for rotation 10 (Cohort 1, preceptors blind to study packet contents) and rotation 2 (Cohort 2. preceptors aware of packet contents). The correlations for the CAP and preceptors' evaluations were not significant for Cohort 1, although nearly so for the otitis scores. For Cohort 2, global evaluation of clinical problem-solving was correlated with the puzzles problem-set, and the mean of specific evaluations was associated with the "terpitis" problem-set and the total CAP score. This component of hypotheses 5 is not supported by these data.

Data for the association of the Watson-Glaser CTAI and preceptors' evaluations is more difficult to interpret. For rotation 10 (Cohort 1, pre-packet), the Assumptions and Arguments subtest scores and the total CTAI score are significantly negatively correlated (*i.e.*, students who scored higher on these were rated lower by preceptors on clinical problem-solving skills). For Cohort 2, evaluations by rotation 2 preceptors were significant and positive for the Inference, Deductions, and Arguments subtests and total CTAI score. The data lend partial support to this part of Hypothesis 5. Although not reported in the table, preceptors' mean global evaluation for rotation 11 (after students had completed the packets) was significant only for time to complete the CAP ($r = 0.62$, $P<0.009$). Students who had taken longer to complete the program (during rotation 10) were rated higher on problem-solving by their preceptors on rotation 11; although the data reveal that total CAP score is negatively correlated with time to complete program.

Also of interest in Table III is the correlation of pharmacy GPA and Therapeutics points with preceptors' evaluations. Pharmacy GPA was negatively, but not significantly correlated with preceptors' evaluations of Cohort 1 students, and was significantly correlated with global evaluations of Cohort 2 students. Mean therapeutics points was negatively correlated with rotation 10 global and mean specific evaluations, and positively correlated with rotation 2 global evaluation. It appears that rotation 10 students with higher average therapeutics points were evaluated lower on problem-solving abilities by their preceptors (who also teach in the therapeutics sequence).

Hypothesis 6 is concerned with the effect of the set of independent variables in this study on the two dependent measures. Students' average points in the Therapeutics sequence was the single significant predictor for the total score on the CAP, and explained over one-third of the variance ($R^2 = 0.36$, $F = 5.09$, $P<0.031$). The one variable that was a significant predictor of the total score on the Watson-Glaser CTAI was students' pharmacy GPA, explaining over 60 percent of the variance in students' scores ($R^2 = 0.64$, $F = 23.2$, $P<0.0001$). Thus the models tested found the student performance measures (GPA or Therapeutics points) to be strong, significant predictors of overall performance on the CAP and the CTAI. It is interesting that preceptors' global evaluation of students' clinical problem-solving was not found to be a predictor of overall performance on the CAP or CTAI. The data did not lend support for Hypothesis 6.

DISCUSSION

The Watson-Glaser CTAI appears to be a useful instrument to assess the specific abilities that students bring to pharmacy school. In this study the CTAI was significantly correlated with both pharmacy grade point average and mean Therapeutics points. One interesting finding which needs further analysis is significance of the average percent correct for each subtest, which ranged from 56 to 84 percent. Given that the students had nearly completed a minimum of six years of college with a focus on critical thinking and problem-solving, the importance of an overall average score of 73 percent needs to be assessed with a larger sample of pharmacy students. There are no norms available for pharmacy students. Future comparisons between P1 and P4 students would be helpful to determine changes in scores on the CTAI, although there were no significant differences between the P4 students in this study and the Fall 1994 P1 students. Mean score on the Inference subtest, for example, was 8.95 (approximately 56 percent correct). This test assesses students' ability to determine whether the information available supports the conclusions drawn. Concerns about having enough patient- and drug-related information to make decisions should alert educators to the need to increase students inference skills.

Although the Basadur Creative Problem-Solving Model has great appeal as one way to teach students about problem-solving in general and specifically about their own preferences, the sample of students was not adequate to demonstrate significant differences among the problem-solving types identified by this instrument. A larger study of pharmacy students would seem in order to evaluate the usefulness of this instrument. The same comments also apply to the Learning Styles Inventory. It appears from these two instruments, and the Myers-Briggs Type Indicator, that students self-select or are selected with very similar patterns or profiles on these instruments. It would be interesting to know if the minority types, as identified on these instruments, follow different patterns while in pharmacy school and in their careers. This will be developed in future research.

The evaluations by preceptors of students' clinical problem-solving abilities was difficult to interpret, particularly those evaluations on the first two rotations when the preceptors did not know what we were assessing in this study. The significant negative correlations with the Watson-Glaser subtests and total score are puzzling. It would appear that students who are better at these problem-solving skills are rated lower on clinical problem-solving ability! Although it may be only coincidental, this relationship disappeared on rotation 11 after the preceptors saw the instruments and were aware of what we were measuring.

A description of the most common patterns or types among P4 pharmacy students at our institution, as depicted by the set of instruments used in this study, reveals the following characteristics. Half of the women and 29 percent of the men in this study were Optimizers, and 29 percent of all students were Implementors on the Basadur CPSP. This suggests that the majority of pharmacy students prefer to use the knowledge they gain for evaluation. They are convergent thinkers who work best on the latter four steps in the problem-solving cycle; they are the problem solvers and problem finishers. Pharmacy students in our study did not demonstrate a strength in divergent thinking or use of knowledge for generation of ideas. This corresponds to a lack of skill and experience in the first four steps in the process: problem sensing, fact finding, definition of the problem, and idea/solution generation. These early steps are essential in provision of pharmaceutical care, and correspond with the ability to get involved when a potential problem develops, getting things started, taking seemingly unrelated information and forming hypotheses, and forming the big picture. The convergent thinkers, on the other hand, take the ideas and potential solutions, once generated, and complete the problem-solving process. Ideally, pharmacy students need to be aware of the whole process, acknowledging and working on the areas where they are weak. Specific exercises can be developed to help students learn to use knowledge to expand their thinking, as well as focusing in on solutions.

The tact that most pharmacy students prefer learning by thinking and by doing (Convergers on the LSI) suggests that passive learning situations are less effective in meeting the educational needs of these students. Furthermore, experiences with active learning, creating situations where students can get their hands dirty and use their sensing character, so to speak, should be developed and provided. Specifically teaching students about learning styles and the strengths and weaknesses of each style may increase appreciation for the contributions the Divergers and Accommodators can make in a learning situation.

Less than 20 percent of pharmacy students in this study were dominant in use of the intuitive mode of information-processing. As one would expect, students show strengths in logical, analytical, and structured thinking. However, clinical problem-solving often requires a less structured approach involving hunches, synthesis, and recognition of patterns. We need to design educational experiences that help students become more balanced in their processing of information, as a situation warrants.

The major personality characteristics of the students involved the sensing and judging poles of the respective dimensions, resulting in the major temperament type of SJ. These students show strengths in working with known facts and standard, and established methods for solving problems; they prefer a planned and orderly way of conducting business and life. There are weaknesses associated with this image of stability, however, in that not all problems have established solutions, and new problems occur frequently which may require unique solutions. In order to generate new ideas and possibilities, a certain degree of flexibility and spontaneity in thinking, and the ability to resist premature closure are required.

The relationship between personality types and effective teaching strategies needs to be explored further for pharmacy students and faculty. Gordon suggests instructors are more likely to understand, and get along with, students of types similar to their own (30). Knowledge of the teaching styles of the various types and the interaction of these styles with student characteristics may provide insight into instructor-student difficulties, particularly in a seminar, laboratory or clerkship setting.

With the changing philosophy in pharmacy practice specifically and health professions education in general, and the demand from external sources for accountability and efficiency in education, it would seem that additional attention needs to be focused on the interactions and relationships of these cognitive and personal style factors, instructor characteristics, and student-centered learning experiences, in order to develop students' competencies in clinical problem-solving. Today's pharmacy graduates need to be facile in all stages of the problem-solving process, and able to integrate a great deal of information to provide care to a specific patient with specific medical and psychosocial needs. They must be willing to become involved with and take responsibility for direct care of that patient. As pharmacy educators we are all responsible for tailoring the learning experiences to meet these goals.

Finally, the authors acknowledge the many limitations in interpretation of these data from this preliminary study. Although over half of the students in each cohort responded and completed the assessment packet, the resulting sample size is small. However, it is reassuring to note that the data from 52 P1 students collected in Fall, 1994, demonstrates very similar results on the Watson-Glaser CTA1, and similar distributions on the MBTI, Basadur CPSP, LSI and CSI. The maximum number of students in the P4 year is usually below 50 at our College. Efforts to motivate students to complete the packets were not as successful as anticipated. Some students were not on the rotation listed in the schedule and had to be tracked down. The finding of negative correlations between preceptors' evaluations and scores on the CTAI is intriguing, and warrants further study. We plan to expand this study to include students from multiple schools to increase the sample size to investigate further the minority temperaments, learning styles, and creative problem-solving styles, and their relationship to student performance measures and the CTAI. The CAP will continue to be revised to increase its validity.

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APPENDIX A. EVALUATION FORM USED BY PRECEPTORS

Evaluation of P4 Student's Problem-Solving Abilities

Instructions: At the end of the present clerkship, please provide the following information on your students. Complete a separate evaluation form for each student.

Preceptor: _____   Student: _____
Clerkship:_____   Rotation Number: _____

1. Please rate student's overall problem-solving abilities by circling the letter that most closely describes this student.

    a. High, able to solve difficult clinical problems, equivalent to an experienced pharmacist-clinician.
    b. Very good, able to solve moderate clinical problems, but with some inadequacies with difficult clinical problems.
    c. Good, able to solve simple and moderate clinical problems, but unable to solve difficult clinical problems.
    d. Fair, able to solve simple problems but unable to solve problems of greater difficulty.
    e. Poor, unable to solve simple clinical problems.

2. Please evaluate student on each of the following aspects of clinical problem-solving, using the scale below. Circle the number corresponding to your evaluation.

    4 = Outstanding
    3 = Competent
    2 = Improvement needed
    1 = Incompetent

    a. Recognizing the existence of a problem.
    b. Defining the nature/requirements of a problem.
    c. Generating more that one set of steps that may solve a problem.
    d. Knowledge acquisition to solve a problem.
    e. Organizing information about a problem.
    f. Critical and logical thinking process related to a problem.
    g. Allocating mental and physical resources to solving a problem.
    h. Monitoring the outcome related to the solution of a problem.
    i. Personal attributes required for problem-solving (*e.g.*, values, attitudes, emotions, confidence).