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THE IMPACT OF RESTRUCTURING ON RESPIRATORY CARE CLINICAL EDUCATION

Crystal L. Dunlevy and Phillip Hoberty
The Ohio State University, Columbus, OH

William F. Galvin
Gwynedd Mercy College, Gwynedd, PA

Abstract

In light of the hospital restructuring debate, there is the possibility that the redesign of respiratory care as we know it, may unintentionally injure academic respiratory therapy. The purpose of this study was to determine how hospital restructuring has affected the clinical curricula of respiratory care education programs and to identify strategies for survival in the evolving atmosphere that exists in health care today. One hundred eighty-six questionnaires were sent to a random sample of respiratory care program directors nationwide. Descriptive statistics were compiled. One hundred twenty-four (67%) program directors responded to the survey. Fifty-five percent indicated that hospital restructuring has affected their clinical curricula. Of those not yet affected, 68% reported that they used paid instructors or program faculty to provide clinical instruction. Strategies are presented that may be useful in minimizing the negative impact of hospital restructuring on the clinical curricula of respiratory care programs.

The Impact of Restructuring on Respiratory Care Clinical Education

In the heat of the hospital restructuring debate, there is the possibility that the downsizing, or redesign of respiratory care as we know it, may unintentionally injure academic respiratory therapy. Downsizing, patient-focused care, and total quality management challenge respiratory care departments to ‘do more with less’. In such an environment, clinical education is often one of the first casualties. In 1993, the American Association for Respiratory Care (AARC) issued its Policy Statement on Health Care Reform and the Role of Respiratory Care (AARC, 1993). The policy called for universal access to health care, delivery-site neutrality, cost containment, and increased emphasis on health promotion. The AARC further encouraged the development of respiratory care practitioners (RCPs) as multicompetent hospital caregivers and forecasted an increased demand for respiratory care in the home setting. Even before hospital restructuring became a part of every health care worker’s vocabulary, Arthur Andersen Consulting conducted a survey for the AARC and reported that respiratory care departments were already expanding into new practice areas, such as bronchoscopy, cardiac rehabilitation, electrocardiograms, electroencephalograms, extracorporeal membrane oxygenation, hyperbaric oxygenation, sleep study, and invasive and noninvasive cardiac testing (Andersen & AARC, 1992). The respiratory care profession has, thus far, met the challenges brought on by restructuring by being an integral part of the decision-making process, remaining informed, and being a ‘team player’. Respiratory care managers have played to the strengths of the RCP by maintaining or strengthening their position within the organization; their presence in the intensive care unit (ICU), coupled with their scientific background and technical training, make RCPs ideal candidates to take on more sophisticated procedures (Bunch, 1992). In so doing, many RCPs have firsthand experience with change in the practice of respiratory care. Many new responsibilities and procedures have been taken on and some relinquished.

Respiratory therapy program faculty have been forced to adapt to this changing clinical picture in order to continue to provide comprehensive, up-to-date clinical instruction for their students. The associate director of the Pew Health Professions Commission encouraged educational programs to conform to the needs of the changing hospital environment or risk extinction (O’Daniel, 1995). The 1992 AARC Consensus Conference suggested that RCPs be multicompetent, multicredentialed professionals who could work well in team-structured environments (Galvin et al., 1995). The purpose of this study was to determine how hospital restructuring has affected the clinical curricula of respiratory care education programs and to identify strategies for survival in the evolving atmosphere that exists in health care today. A review of the literature indicated that although the impact of various aspects of restructuring on clinical curricula have been evaluated in other professions, no study has been previously published that addresses the issue in the respiratory care profession (Meyers, 1995; Satran et al., 1993; Reimer, 1992).

Materials and Methods

A two-page questionnaire, consisting of four core questions was developed by the investigators. It was subsequently reviewed for readability and content validity by three respiratory care program faculty members at separate institutions, three clinical instructors, two respiratory care senior-level students, and a statistician. The document was revised according to feedback from these individuals.

The study population consisted of respiratory care educational programs in the United States, as recorded in a list of 372 accredited programs published in 1995 by the Joint Review Committee for Respiratory Therapy Education. The list was comprehensive, including respiratory care programs offering the baccalaureate degree, associate degree, and certificate of completion. Beginning with Alabama and ending with Wyoming, the programs were numbered 1 through 373. The principal investigator tossed a coin, assigning heads to even-numbered programs from the list and tails to odd-numbered programs. As a result of the coin toss, programs listed as odd numbers were chosen to comprise the sample. The study population was comprised of 131 programs offering the associate degree, 46 programs offering a certificate of completion, and 19 baccalaureate programs. Program directors from each of these 186 institutions were mailed a copy of the survey and a self-addressed, stamped envelope. Subjects were asked to return the completed questionnaires within two weeks of receipt. Statistics were descriptive in nature with responses tallied and total number of responses for each item reported. Anecdotal remarks were compiled and are included in the discussion section.

Results

One hundred twenty-four program directors responded to the survey (67% response rate). Baccalaureate program response rate was 88%, associate degree program response rate was 63%, and certificate program response rate was 54%. Respondents indicated that the majority of clinical education is provided by respiratory therapy program faculty, followed by paid preceptors as the second most frequent providers. Table 1 contains data that show how clinical education is provided to students. Sixty-eight respondents (55%) indicated that hospital restructuring has affected their clinical curricula, while 56 respondents (45%) reported that they were unaffected, thus far. Of those 56 respondents, 38 (68%) reported that they used paid clinical instructors or respiratory care program faculty to provide clinical instruction.

Table 1
Provision of Clinical Education among Respiratory Care Education Programs (N=124)

Private Means of Providing Clinical Education (Respondents Could Select > 1 Response)	Number of Respondents
Affiliate reimbursed by school	18
Affiliate required to provide instruction (per contract)	41
Volunteer clinical instructors	37
Paid clinical instructors	43
Respiratory care program (college/university) faculty	79

Table 2 includes information about how hospital restructuring is affecting programs' clinical rotation schedules. Thirty-five respondents indicated that their affiliate departments were accepting fewer students per clinical rotation, while 33 respondents reported a change in the services provided by their affiliates' respiratory therapy departments.

Table 2
Effects of Hospital Restructuring on Respiratory Care Programs' Clinical Rotation Schedule (N=68) (56 Respondents Reported that their Programs Were Currently Unaffected by Hospital Restructuring)

Private Effect of Hospital Restructuring on Respiratory Care Program Clinical Rotation Schedule (Respondents Could Select > 1 Response.)	Number of Respondents
Departments no longer willing to accept respiratory care students	16
Departments accepting fewer respiratory care students	33
Departments unable to provide volunteer ('free') instructors	21
Change in services provided by respiratory care practitioners	35
Specific rotations canceled	8

Table 3 lists the frequency of alternative strategies used to counterbalance the negative effects of restructuring. Forty-seven respondents indicated that they are using alternate sites in order to provide clinical rotations; these sites included subacute care facilities, skilled nursing facilities, home care agencies, pulmonary rehabilitation programs, and smaller, outlying community hospitals. Thirty-four respondents indicated that they are trying to send better-prepared students to clinical rotations by strengthening the laboratory component of their programs. Others indicated that they had recently added phlebotomy, electrocardiogram, and sleep laboratory rotations to their existing clinical-site offerings. It is interesting to note that 14 respondents indicated that they are using nursing or other health professionals as clinical instructors.

Table 3
Alternative Strategies Used To Counteract Effects of Hospital Restructuring on the Clinical Component of Respiratory Care Education Programs (N = 68)

Strategy (Respondents Could Select > 1 Response.)	Number of Respondents
Use of alternate clinical sites (outpatient care, subacute, community hospitals)	47
Requiring fewer clinical hours in curriculum	2
Requiring different clinical rotations at affiliate	16
Increased use of other health professionals or nurses as preceptors	14
‘Beefing up’ respiratory care labs	34

Table 4 reports data on how respiratory care programs are ‘beefing up’ their laboratories in an effort to better prepare students for clinical rotations. All respondents to this section indicated that they were adding, or planning to add in the near future, some type of computer-assisted instructional tool. More than half are also using more ‘real-life’ examples in their labs, including buying better quality manikins, using more role play, using real patient cases, and purchasing more up-to-date equipment.

Table 4
Methods Used To Enhance the Quality of Respiratory Care Laboratories

Method (Respondents Could Select > 1 Response) (N=34)	Number of Respondents
Requiring more lab hours In curriculum	11
Using more ‘real-life’ lab experiences (case studies, critical pathways, role play)	19
Adding or increasing amount of open lab time	18
Using lab instructors for open lab time	11
Computer-assisted learning	34

Discussion

It is clear from the data that hospital restructuring is effecting the clinical curricula of respiratory care education programs. How we allow it to affect us is, in large part, up to us. Restructuring affords new opportunities to acquire new skills. While some RCPs may take responsibility for routine activities, such as patient hygiene, many RCPs are seizing the opportunity to take on more sophisticated procedures such as hemodynamic monitoring and sleep study. In order to do this, some less complex procedures (i.e., incentive spirometry, pulse oximetry checks, oxygen rounds) may need to be shifted to the responsibility of other health care professionals. Like other professional groups, RCPs are inclined to ‘hold on’ to every procedure; we need to exercise flexibility in the area of role delineation. If certain simpler procedures traditionally performed by respiratory therapists are given over to another caregiver, the opportunity to educate presents itself. Whether nursing personnel or patient care technicians are to assume these skills, someone has to teach them. As respiratory care program faculty, we are in the unique situation to assist the hospital department by offering our skills and taking responsibility for such training.

As a result of the implementation of critical pathways, therapist-driven protocols, and total quality management approaches, RCPs need critical-thinking and assessment skills. The RCP is no longer in the position of simply carrying out orders prescribed by the physician. But critical thinkers are made, not born. There is no better place to begin practicing these skills than the classroom and the respiratory therapy laboratory. Students require lots of practice working through critical pathways, role playing, and selecting the appropriate information from care histories. We need to shift our focus in our educational programs from task-orientation and psychomotor skilling to the development of critical evaluation and assessment skills. Students who have some background in the research process are better able to perform total quality management activities and spend time on the development of basic research skills.

The results of this study also indicate that respiratory care programs are facing greater difficulty placing students in clinical rotations. In order to change this, we have to adopt a ‘what-can-we-do-for-you’ negotiating style. There are a myriad of ways that we can make ourselves useful to the hospital and show our appreciation by offering in-services to department personnel or providing training to other departments who are taking on ‘respiratory’ responsibilities. We can assist departments in the development of protocols and critical pathways, or we can actively participate in the clinical instruction of our students (recall that those faculty who actually ‘do’ clinical instruction are having fewer problems related to restructuring).

Perhaps, one of the most important ways we can effect change is in the preparation of students. We need to be positive; the way in which our students come to perceive other health care professionals and the situations they encounter at the clinical affiliate is largely a reflection of our own attitudes. As educators we need to identify the strengths of our programs and students and play to them. We should send students who are well prepared, self directed, reliable, and motivated, and coach them actively in these areas. The literature abounds with studies showing that preceptors teach because of the intrinsic rewards that they receive from these types of students (Dunlevy & Wolf, 1992a, 1992b, 1994; Gwyer, 1993). Let students know that it is important to show appreciation to their clinical instructor(s) by saying "thanks for your time" at the end of the day. Let the students know that you will be checking to see if they are doing these things, and make it worth their while to do so.

The changing arena in health care today is nothing new. This has not been the first storm that respiratory care educators have weathered, and it is unlikely to be the last. In order to survive, we must be positive, willing to compromise, informed and involved, objective; and we must communicate often with students and preceptors. Educators are in the enviable position of being able to effect change in the practice of respiratory care, the lives of students, and the patients for whom they care. If we are proactive rather than reactive, we can influence the impact that hospital restructuring has on our programs and on our profession. In his autobiography, Henry Adams reflected upon the nature and purpose of education. He celebrated the importance of the teacher: "A teacher affects eternity; he can never tell where his influence stops."

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Author Note

At the time this paper was accepted for publication, Crystal L. Dunlevy, EdD, RRT, was Associate Professor & Director of Clinical Education; and Phillip Hoberty, EdD, RRT, is Assistant Professor, Respiratory Therapy Division. Dr. Dunlevy is now a faculty member at Georgia State University, Atlanta, Georgia. William F. Galvin, MSEd, RRT, is Program Director, Respiratory Care.

Correspondence concerning this article should be addressed to Crystal L. Dunlevy, Georgia State University, Atlanta, GA 30303-3083.

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EFFECTS OF CONTENT, PROCESS, COMPUTER-ASSISTED INSTRUCTION, AND CRITICAL-THINKING ABILITY ON STUDENTS' PERFORMANCE ON WRITTEN CLINICAL SIMULATIONS

David C. Shelledy, Mark A. Valley, and Douglas L. Murphy
The University of Texas Health Science Center at San Antonio

Michael E. Carpenter
St. Philip's College, San Antonio, Texas

We compared the effects of content instruction (CI), process instruction (PI), computer-assisted instruction (CAI), and critical-thinking ability on student performance on a written latent-image clinical simulation problem (CSP). CAI and CI were associated with significant improvements in students' decision-making (DM) scores. PI was associated with significant improvements in students' information-gathering (IG) scores. It appears that understanding the exam process improves student IG performance, while content knowledge and CAI improve DM. There was a moderate correlation between critical-thinking ability and performance on IG. Critical thinking was not related to initial DM performance, but may have had an impact on students' ability to gain from instruction and practice.

EFFECTS OF CONTENT, PROCESS, COMPUTER-ASSISTED INSTRUCTION, AND CRITICAL-THINKING ABILITY ON STUDENTS' PERFORMANCE ON WRITTEN CLINICAL SIMULATIONS

Introduction

In 1979 the National Board for Respiratory Care (NBRC) began administering clinical simulation patient management problems as part of the examination system for credentialing registered respiratory therapists (Reinecker, 1985; Rosen, 1983; Traband & George, 1994). Previously, oral examinations were used in an attempt to assess conditional problem-solving abilities. Oral examinations had certain logistical problems, and the use of clinical simulation examinations corrected these problems. Candidates for the oral examinations were often required to travel long distances to limited test sites (Rosen, 1983). The examinations were subjective, expensive to administer, and required a trained cadre of oral examiners. Only a limited number of the total applicant pool could be tested at a given time (Rosen, 1983; Traband & George, 1994). Variations in individual examination content and bias of examiners may have resulted in inconsistent and subjective outcomes (Rosen, 1983). The implementation of the written clinical simulation examination allowed for multiple testing centers with increased frequency of test dates (Traband & George, 1994). Individual examiner bias and subjectivity were eliminated (Rosen, 1983).

Clinical simulation testing is thought to assess problem-solving ability, critical thinking, judgment, and clinical decision-making competence in a way that may not be measured using multiple choice tests (Bersky & Yocom, 1994; Reinecker, 1985). Clinical simulation testing has been used to assess competence in medicine and respiratory care and is currently being considered in the field of nursing (Bersky & Yocom, 1994; Norcini, 1986; Reinecker, 1985; Rosen, 1983; Traband & George, 1994).

Computer-assisted instruction (CAI) offers a method to provide automated, individualized instruction that allows students to proceed at their own pace (Hmelo, 1989; Shelledy, 1987). CAI can provide branching in the instructional program with immediate feedback based on the individual student's response (Chop, 1989; Reinecker, 1985; Shelledy & Mikles, 1987). CAI offers an alternative teaching method that can be as effective as classroom instruction while offering greater freedom in scheduling student access without consuming additional instructor time (Hmelo, 1989; Shelledy & Mikles, 1987). By increasing instructional efficiency, CAI may provide educators with more time to focus on students with additional problems (Hmelo, 1989).

CAI is able to reinforce previous learning and may help students gain clinical problem-solving skills without jeopardizing patients (Boh, 1987; Chop, 1989; Hmelo, 1989; Reinecker, 1985; Shelledy, 1987). Computerized clinical simulation testing is a way to realistically simulate clinical decision making and evaluate clinical competence (Bersky & Yocom, 1994). Many respiratory care educators use CAI for its simulation capabilities to prepare students for the NBRC examination (Chop, 1989; Reinecker, 1985). Schools of dentistry, pharmacy, nursing, medicine, and other allied health professions incorporate clinical simulation software in their training programs (Bersky & Yocom, 1994; Boh, 1987; Chop, 1989; Friedman, 1995; Norcini, 1986; Reinecker, 1985).

Hmelo (1989, 1990) offers an excellent review of the published literature regarding the use of CAI in health professions education. It is interesting that Hmelo (1989-90) states that most of the literature is descriptive in nature, and that only 7 of more than 100 papers reviewed contained detailed evaluations of the effectiveness of the computer programs used. There have been problems in assessing the effect of CAI on problem solving and critical thinking due to the difficulty in finding a suitable measurement tool (Bitzer & Bitzer, 1973; Hmelo, 1989, 1990). There is some evidence that students acquire better decision-making skills with the use of a computer (Jones & Keith, 1983). There also may be relationships between critical thinking, length of education, and types of instruction; however, these relationships need further study (Dobrzykowski, 1994; Dowd, 1991; Miller, 1992; Pond, Bradshaw & Turner, 1991; Robbins, 1988). Hmelo also writes that despite the widespread use of CAI in health education, very little research has been done to validate its use.

The NBRC Examinations as a Measure of Program Success

Graduates of advanced-level respiratory care education programs are expected to demonstrate the ability to comprehend, apply, and evaluate information relevant to the role of the respiratory therapist (Joint Review Committee for Respiratory Therapy Education [JRCRTE], 1995). Current accreditation guidelines for therapist programs require that pass rates on the NBRC written and clinical simulation registry examinations be used as measures of an education program's success in meeting this standard. As a measure of advanced-practitioner education program effectiveness, the number of graduates who go on to become registered respiratory therapists (RRT) may be one of the most important indicators of program success.

National new graduate pass rates on the NBRC written registry examinations generally range from about 75 to 77% for first-time takers of the exam (NBRC, 1994, 1995). Pass rates for first-time examination takers for the NBRC clinical simulation examinations averaged 53% for the period of 1989-1994 (Traband & George, 1994). The first-time pass rate (i.e., cumulative score) for both exams, which must be passed for takers to be awarded the RRT credential, must be less than or equal to the pass rate of the most difficult examination. Consequently, first-time pass rates on the combined examinations for registry may be less than desirable. If one purpose of advanced-practitioner education programs is to prepare students to become registered respiratory therapists, it is apparent that, on average, the education community has not demonstrated a great deal of success in achieving this goal. First-time and repeat candidate registry examination pass rates for the period 1993-1995 are found in Figure 1 (NBRC, 1994; 1995; 1995).

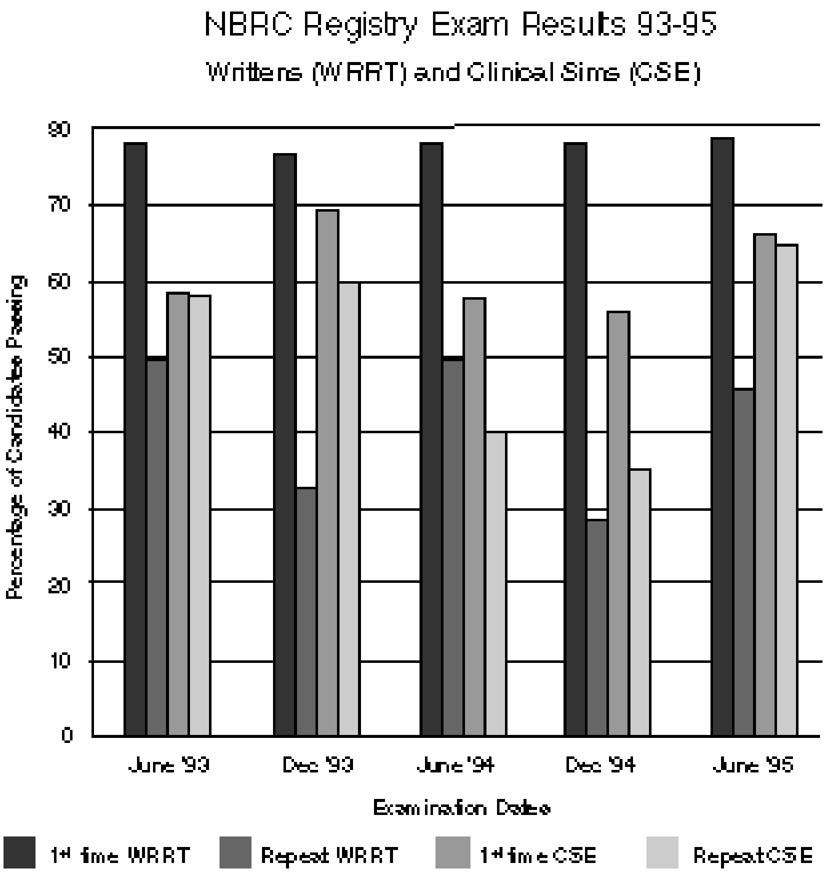

Figure 1. First time and repeat candidate pass rates for the National Board for Respiratory Care written registry examinations and clinical simulation examinations for period 1993 through June of 1995. NOTE: WRRT = written registry examination; CSE = clinical simulation examination.[1]

[1]Data used to develop the figure from "1993 Examinations in Review," 1994; NBRC Horizons, 20(2), p. 7; "'94 Examination Statistics," 1995; NBRC Horizons, 21(2), p. 6-7; and "NBRC Bulletin Board: RRT Examination," 1995; NBRC Horizons, 25(5), p. 8.

Problem

While education programs have been modestly successful in preparing graduates to pass the NBRC written registry examinations, they have had limited success in preparing graduates to pass the clinical simulation examination. We sought to determine if specific types of instruction can be useful in improving performance on the clinical simulation examination.

Factors That May Be Related to Examination Performance

Candidates' success on the NBRC clinical simulation examination may be related to their achievement or abilities in five broad areas. First, successful candidates should possess content knowledge in the area being tested. For example, in completing a clinical simulation problem (CSP) concerning the care of a patient with chronic obstructive pulmonary disease (COPD), the successful candidate should possess content knowledge related to the diagnosis, treatment, and application of respiratory care to COPD patients. We hypothesized that instruction about content related to the care of a specific patient condition tested by a CSP would improve student performance.

Second, successful clinical simulation examination candidates should understand the process of taking the examination. This includes understanding the mechanics of the exam, how points are awarded, and techniques to maximize performance (e.g., making a map). Even expert clinicians may perform poorly on clinical simulation exams if they do not understand the mechanics of the test. We hypothesized that instruction about the process of taking the exam would improve student performance on written CSPs.

Third, it was believed that practice with actual SPs would enhance a candidate's performance on the real thing. Learning usually improves with repetition and performance tends to improve with practice. Because CAI clinical simulations are widely available, many clinical simulation exam candidates use these programs in preparation for taking the actual test. Using a commercially available computer simulation run in the teach mode, we evaluated the effect of CAI on students' performance on a written latent-image simulation. The computer program provides the student with feedback based on their choices as the student works through the CSP.

Fourth, it was hypothesized that generalized critical-thinking skills and problem-solving ability would be related to candidates' success on specific clinical simulation problems. Clinical simulations purport to test candidates' problem-solving and critical-thinking abilities. It would seem that individuals with strong critical-thinking skills would tend to outperform those with weaker critical-thinking abilities.

Fifth, it is generally thought that clinical experience caring for a variety of patients will improve candidates' scores on the clinical simulation examinations (George & Oslick, 1995; Traband & George, 1994). Prior to 1983, a year of clinical experience was required before candidates were allowed to sit for the NBRC clinical simulation exams (NBRC, 1995). In spite of this experience requirement, new candidate pass rates on the exam were in the 50-55% range. Examination candidates prior to 1983 did not do appreciably better than today's candidates who do not have a specific experience requirement.

This raises the question as to what amount and type of clinical experience is most beneficial. Last, it should be recognized that a major factor in determining performance on clinical simulation examinations may be the amount of time and effort spent by the individual student in preparation for the exam.

Purpose

The purpose of this study was to compare the effects of content instruction (CI), process instruction (PI), and CAI on student performance on a written latent-image clinical simulation problem. Further, the study assessed the relationship of general critical-thinking ability to performance on a written clinical simulation problem. Research questions addressed were:

1. What impact does content instruction have on student performance on written latent-image clinical simulation problems?
2. What impact does knowledge of the structure and process of taking clinical simulation problems have on student performance on written latent-image clinical simulation problems.
3. What impact does practice using CAI programs with feedback have on student performance on written latent-image clinical simulation problems?
4. What is the relationship between general critical-thinking skills and performance on clinical simulation problems?

Method

An available sample of all first-year students (*N* = 24) enrolled in a community college respiratory care program were selected for study. All students had successfully completed all program prerequisites and one semester of academic and clinical respiratory care coursework. The students were pretested using a CSP provided by the NBRC. The students were then randomly assigned to three groups. Each group received one hour of instruction: Group 1—CAI practice using a commercially available clinical simulation run in the teach mode (Medi-Sim, Inc.); Group 2—CI relevant to the written simulation; Group 3—PI over the structure of written simulations and techniques to maximize performance. Outlines of the instruction provided for each group are found in Tables 1-3. Following instruction, students repeated the CSP. Students also completed the Watson-Glaser Critical-Thinking Appraisal. This test is designed to determine subjects' ability to reason analytically and logically. The Watson-Glaser uses five subtests to assess the subject's ability to make inferences, recognize assumptions, perform deduction, and interpret and evaluate arguments (Berger, 1985). The scores on these five subtests are combined to generate an overall critical-thinking score (Berger, 1985).

Table 1

Outline of the Optimal Path for the Computer Simulation: Adult Asthmatic

I. Initial menu choice: Teach mode—provides immediate feedback to the student following each selection during the simulation
II. An adult asthmatic in the emergency room in acute distress
  A. Decision making: Administer low flow oxygen
  B. Information gathering: Gather patient assessment data and blood gases
  C. Decision making: Administer bronchodilator therapy
  D. Decision making: Patient condition worsens, increase oxygen flow
III. Time passes, patient condition worsens
  A. Decision making: Intubate and mechanically ventilate
  B. Decision making: Select mode of ventilation
  C. Decision making: Select initial ventilation setting
IV. Patient stabilized, problematic secretions
  A. Decision making: Begin chest physical therapy
V. Four days pass on the ventilator—patient in IMV mode
  A. Decision making: Decrease the IMV rate
  B. Decision making: Based on assessment data provided, institute "T" tube trial
  C. Decision making: Based on assessment provided, extubate the patient

NOTE: IMV = intermittent mandatory ventilation; "T" tube = Briggs adaptor. Adapted from the computer simulation, "Clinical Simulation in Respiratory Therapy: Adult Asthmatic," B. Kacmarek, 1991, Williams and Wilkins Electronic Media, with permission of the author.

Table 2
Management and Monitoring of the Ventilated Patient Lesson Plan Outline

I. Objectives
II. Physical assessment of the mechanically ventilated patient
  A. General appearance
    1. Color
    2. Sensorium
  B. Vital signs
    1. Heart rate
    2. Respiratory rate
    3. Blood pressure
    4. Temperature
      a. Presence of infection
  C. Chest examination
  D. Miscellaneous
  E. Lab data
    1. Arterial blood gases
    2. Chest x-ray
III. Monitoring typical ventilation parameters
  A. Mode
  B. Tidal volume
    1. Calculating ideal body weight
  C. Frequency of mechanical breaths
  D. Peak inspiratory pressures
  E. F_{IO2}
    1. If > 40%, consider PEEP
  F. Flow
  G. Compliance
  H. PEEP
  I. Inspired gas temperature
  J. Alarm
  K. Other important checks
IV. Administering medication "in-line" to a ventilator patient
  A. Medications
  B. Procedure
V. Troubleshooting the ventilator for typical problems and alarm states
  A. High pressure
  B. Low pressure
  C. Complications
    1. Pneumothorax
  D. Corrective actions

NOTE: Developed by David C. Shelledy.

Table 3
Clinical Simulation Examination Structure and Process Lesson Plan Outline

I. Objectives
    A. Insight into exam structure and content
    B. Strategies and techniques for successful examination performance
II. Definition of a simulation
III. Types of simulations
    A. Models
    B. Oral simulations
    C. Computer simulations
    D. Latent image hidden response written simulation
IV. General rules
    A. Take charge
    B. Follow standards of practice
    C. Take your time
    D. Think before acting
    E. Follow directions
V. Design
    A. Scenario
    B. Information gathering
    C. Decision making
VI. The scenario
    A. Purpose
    B. Main ingredients
    C. Example
VII. Information gathering
    A. Identify the problem
    B. Techniques to succeed
    C. Process
    D. Criteria
    E. Key elements to select
    F. Key elements to avoid
    G. Triggers
    H. Identify the problem
VIII. Decision making
    A. Item selection
    B. Physician disagrees
        1. What to do
        2. Identify the problem
IX. Selection of exam problem
X. Branch mapping
XI. Types of branching
    A. Example of single branching

- B. Example of complex branching
- XII. Routes and importance of making a map
- XIII. Scoring
- XIV. Related terms
  - A. Alternate sections
  - B. Option
  - C. Responses
  - D. Bridge statement
- XV. Common errors
  - A. Technical
  - B. Nontechnical
- XVI. Summary and points of emphasis

NOTE: PEEP = positive end-expiratory pressure. Adapted from "Preparing for Successful Completion of the Clinical Simulation Exam" by W. Galvin, 1992, Gwynedd Mercy College, Gwynedd, PA, with permission of the author.

Data Analysis

Pretest scores IG and DM scores for the three groups were compared using the Kruskal-Wallis ANOVA. No significant difference ($p > .05$) on pretest scores would indicate that the three groups were similar prior to instruction (CSS, 1991). Pretest and post-test scores for information gathering (IG) and decision making (DM) were compared to determine if there were significant improvements using the Wilcoxon matched pairs test for dependent samples (CSS, 1991). Overall critical-thinking scores were compared to pretest scores, post-test scores, and change scores for IG and DM using the Pearson product moment correlation to determine if there were significant ($p < .05$) correlations between sets of scores (Ary, Jacobs, & Razavich, 1985).

Results

Individual scores, change scores, group means, and standard deviations are reported in Table 4. There were no significant differences in pretest scores for IG ($p = .31$) or DM ($p = .37$) using the Kruskal-Wallis ANOVA (Table 5). Following instruction, change scores ranged from -9 to +14 in IG and -20 to +80 in DM for the CAI group. Change scores ranged from -5 to +36 in IG and 0 to +70 in DM for the CI group. Individual change scores for the PI group ranged from -14 to +27 for IG and -20 to +90 for DM. The CAI group mean scores improved +5 (*SD* = 10) for IG and +31 (*SD* = 41) for DM. The CI group mean scores improved +4 (*SD* = 14) for IG and +21 (*SD* = 24) for DM. The PI group mean scores improved +8 (*SD* = 13) for IG and +11 (*SD* = 36) for DM.

Table 4

Comparison of the Scores of Three Student Groups on a Written Simulation Problem

		Information-Gathering Scores			Decision-Making Scores		
Student	Instruction	Pretest	Post-Test	Change	Pretest	Post-Test	Change
1	CAI	46	55	+9	50	70	+20
2	CAI	86	77	-9	30	100	+70
3	CAI	73	82	+9	-30	50	+80
4	CAI	73	73	0	70	50	-20
5	CAI	77	68	-9	100	90	-10
6	CAI	77	91	+14	40	100	+60
7	CAI	55	68	+13	0	60	+60
8	CAI	46	59	+13	60	50	-10
Mean (*SD*)		67 (15)	72 (12)	+5 (10)	40 (41)	71 (22)	+31 (41)
9	CI	77	86	+9	40	40	0
10	CI	77	77	0	60	100	+40
11	CI	96	91	-5	100	100	0
12	CI	50	86	+36	80	80	0
13	CI	73	73	0	40	60	+20
14	CI	77	77	0	30	100	+70
15	CI	73	68	-5	80	100	+20
16	CI	91	91	0	80	100	+20
Mean (*SD*)		77 (14)	81 (9)	+4 (14)	64 (25)	85 (23)	+21 (24)
17	PI	68	73	+5	10	100	+90
18	PI	91	77	-14	90	100	+10
19	PI	46	68	+22	80	60	-20
20	PI	73	82	+9	80	100	+20
21	PI	86	86	0	20	-10	-30
22	PI	73	77	+4	70	70	0
23	PI	59	86	+27	50	70	+20
24	PI	59	73	+14	100	100	0
Mean (*SD*)		69 (15)	78 (7)	+8 (13)	63 (33)	74 (38)	+11 (36)

NOTE: CAI = computer-assisted instruction; CI = content instruction; PI = process instruction; *SD* = standard deviation.

Table 5

Results of the Kruskal-Wallis ANOVA by Ranks Test for Comparing Pretest IG and DM Scores on a Written Latent-Image Clinical Simulation Problem

Independent Variable Group Assignment	Dependent Variable Pretest IG Scores Mean (*SD*)	*N*	Sum of Ranks	*H* (2,24)	*p*
CAI	67 (15)	8	86.5	2.32	.31
CI	77 (14)	8	124.5		
PI	69 (15)	8	89.0		
Independent Variable Group Assignment	**Dependent Variable Pretest DM Scores Mean (*SD*)**	***N***	**Sum of Ranks**	***H* (2,24)**	***p***
CAI	40 (41)	8	77.0	2.01	.37
CI	64 (25)	8	111.0		
PI	63 (33)	8	112.0		

NOTE: CAI = computer-assisted instruction; CI = content instruction; PI = process instruction; IG = information gathering; DM = decision making; *SD* = standard deviation; *N* = number of subjects; *H* = Kruskal-Wallis matched pairs test (This is a nonparametric alternative to between groups one-way analysis of variance. The interpretation is similar to the parametric one-way ANOVA, except that it is based on ranks rather than means); *p* = probability.

The results of the Wilcoxon matched pairs test for comparing pretest and post-test student scores are found in Table 6. There were significant improvements in IG for PI ($p = .05$) while DM improved significantly for CAI ($p = .05$) and CI ($p = .02$) There were no significant differences in pretest and post-test scores ($p > .05$) in IG for CAI or CI or in DM for PI.

Table 6

Results of the Wilcoxon Matched Pairs Test for Comparing Pretest and Post-Test Student Scores on a Written Latent-Image Clinical Simulation Problem.

Group	Exam Section	*N*	*T*	*p*
CAI	IG	8	5.0	.06
	DM	8	6.5	.05*
CI	IG	8	3.0	.23
	DM	8	0.0	.02*
PI	IG	8	4.5	.05*
	DM	8	8.0	.30

NOTE: CAI = computer-assisted instruction; CI = content instruction; PI = process instruction; IG = information gathering; DM = decision making; *N* = number of subjects; *T* = Wilcoxon matched pairs test (This test is a nonparametric alternative to the *t* test for dependent samples, except that it is based on ranks rather than means); *p* = probability.

* Significant at the .05 level for a one-tailed test.

The correlations between the Watson-Glaser Critical-Thinking Appraisal, pretest, post-test, and IG and DM change scores are found in Table 7. There was a moderate, but significant correlation between general critical-thinking ability, pretest IG (r = .60; p = .002), and post-test IG (r = .55; p = .006). There was not a significant relationship between general critical-thinking ability and pretest DM (r = .25; p =.24). There was a weak, but significant correlation between general critical-thinking ability and post-test DM (r = .49; p =.015).

Table 7

Pearson-Product Moment Correlations between Critical Thinking Scores, and Pretest, Post-Test and Change Scores for Information Gathering (IG) and Decision Making (DM)

Pretest		Post-Test		Change Scores	
IG	DM	IG	DM	IG	DM
r = .60 (p = .002)*	r = .25 (p = .24)	r = .55 (p = .006)*	r = .49 (p = .015)*	r = -.30 (p = .16)	r = .16 (p = .46)

NOTE: IG = information gathering; DM = decision making; r = Pearson product moment correlation; p = probability.

* $p < .05$

There was no relationship between critical-thinking ability and IG change scores (r = -.30; p = .16) or DM change scores (r = .16; p = .46).

Discussion

Pretest Results

There were no significant differences (p = .31) between the three groups on pretest IG and DM portions of the written simulation, indicating that the groups were evenly matched prior to receiving instruction.

Information Gathering

PI was useful in significantly improving IG scores for most of our students. Six of 8 students (75%) receiving PI improved their post-scores from 4 to 27 points. Post-test scores for those receiving PI improved, on average, 8 points (p = .05). One student showed no improvement and one student's post-test scores declined following PI. It appears that knowledge of the objectives, design, exam structure, mechanics of the test, scoring, branch mapping, and techniques to maximize scores was useful in improving IG for most students.

CI was of little value in improving our students' information-gathering skills. While average scores for information gathering did improve for students receiving CI, the improvement was not statistically significant (p = .23). Further, 6 of 8 students (75%) showed no improvement or a decline in performance following instruction. Frankly, we found this to be surprising. At least for our sample, additional instruction regarding the respiratory care management of the disease state or condition tested by the CSP did not improve students' ability to select appropriate items from information-gathering sections of the problem. It appears that performance on information-gathering sections of clinical simulations may not be as strongly related to content knowledge as one might assume.

CAI may be of some value in preparing students to succeed on information-gathering sections of clinical simulation examinations. Mean post-test IG scores improved 5 points following CAI, and this improvement approached clinical significance (p = .06). Five of 8 students (62.5%) showed improvement on the post-test, one student showed no change, and two students' scores declined on the post-test following CAI. Thus, CAI may be of value in improving some students' IG scores.

To summarize, the results suggest that CI was of little value in improving IG for our students. CAI may be of some value in improving students IG scores, though our results do not clearly support this conclusion. The good news is that most students receiving process instruction showed a significant improvement in information-gathering scores. We believe that PI is an important method to consider when preparing students to succeed on the clinical simulation examinations.

Decision Making

Mean post-test scores for DM improved 31 points for the group receiving CAI (p = .05). Five out of 8 students (62.5%) receiving CAI improved their scores from 20 to 80 points following instruction. Three students receiving CAI showed a decline in their scores following instruction. Thus, CAI was useful in improving most, but not all students' DM scores.

Mean post-test scores for DM improved 21 points for the group receiving CI (p = .02). With respect to CI, 5 of 8 students (62.5%) improved their DM scores from 20 to 70 points following instruction. Three students receiving CI showed no change in DM, one achieved 100% on both the pretest and post-test. Thus, CI appears to be useful in improving most students' DM scores.

There was no significant improvement in DM for those receiving PI (p = .30). Thus, understanding the mechanics of the test was of little value in improving our students performance in DM.

To summarize, CI significantly improved DM performance. It appears that success in DM is related to content knowledge regarding the respiratory care management of the disease state or condition tested by the CSP. Instruction related to content outline of the NBRC clinical simulation examination should be helpful in preparing students for success, at least on DM sections of the exam. CAI using a commercially available clinical simulation also was helpful in improving DM scores. The use of CAI clinical simulation programs in NBRC exam preparation should be considered.

Critical Thinking and Clinical Simulation Exam Performance

There was a moderate correlation between critical-thinking ability and students' scores on the pretest (r = .60; p = .002) and post-test (r = .55; p = .006) IG sections of the CSP. Thus, it appears that students with good general critical-thinking abilities may perform better on IG sections of clinical simulation exams than those with poor critical-thinking abilities.

There was not a significant relationship between critical thinking and pretest DM scores (r = .25; p = .24). This was surprising in that clinical simulation exams purport to measure problem-solving and applied critical-thinking ability. Perhaps our sample was too small to demonstrate a relationship. Further, the CSP we used may not be representative of the domain of interest. The possibility should be considered, however, that success in making correct decisions on CSPs may not be as strongly related to general critical-thinking ability as is commonly thought. There also was no relationship between critical-thinking ability and the IG and DM change scores, indicating that the degree of improvement in IG and DM scores following instruction was not related to general critical-thinking ability.

There was a weak, but significant relationship between critical-thinking ability and CSP post-test scores for DM (r = .49; p = .015). Those with good critical-thinking abilities tended to do somewhat better in DM following instruction.

Limitations and Recommendations for Further Study

We found a relationship between CI, CAI, and success with DM. There also were clear relationships between process instruction, critical-thinking ability, and success with IG.

The unexpected findings of this study included a poor correlation between general critical-thinking ability and DM and the lack of a relationship between content instruction and IG. These findings need to be verified by further study. The relationship between general critical-thinking ability and real-life decision making in the clinical setting needs to be explored. Further study is also needed to determine if there is a relationship between specific respiratory care content knowledge and performance on IG sections of clinical simulation problems. The relationships between clinical simulation exam performance and real-life clinical problem-solving and critical-thinking ability also needs further study.

Caution must be used in interpreting the results of this study, for several reasons. Sample size was small, and the sample may not be representative of the larger population. The CSP used may not be a good example of actual NBRC simulations currently in use. Further, the use of a pretest may have inadvertently improved student scores on the post-test by providing practice with the written CSP format. In addition, the instruction provided may not have been powerful enough to generate a strong effect because of the content or short duration (1 hour). Lastly, the instruction provided may not be representative of other forms of PI, CI, or CAI.

Recommendations for Practice

While our study raises a number of interesting questions, respiratory care educators are still left with the problem of trying to adequately prepare students for success on the NBRC registry examinations. Our results support the contention that students should receive instruction covering the objectives, design, exam structure, mechanics of the test, scoring, branch mapping, and techniques to maximize scores, as this may be useful in improving IG performance. Students should also receive instruction based on the NBRC clinical simulation examination content matrix, as this may improve DM performance. CAI using commercially available clinical simulations should also be considered, as our study provides evidence that CAI can be useful in improving DM and may be useful in improving IG. The role of clinical experience in improving candidates' performance on CSPs and the relationships between critical thinking and clinical problem solving need further study.

Conclusions

CAI and CI were associated with significant improvements in students' DM scores. PI was associated with significant improvements in students' IG scores. It appears that understanding the exam process has the greatest impact on student performance in IG, while content knowledge and CAI practice have the greatest impact on DM. There was a moderate correlation between critical-thinking ability and performance in IG. Critical thinking was not related to initial DM performance, but may have had an impact on students ability to gain from instruction and practice. There was a large degree of variation in individual student scores for each form of instruction suggesting that a given method may not be effective for all students.

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Authors' Note

David C. Shelledy, PhD, RRT, Chairman, and Mark A. Valley, MEd, RRT, Assistant Professor, Department of Respiratory Care, Douglas L. Murphy, PhD, Evaluation Specialist, Division of Instructional Development, The University of Texas Health Science Center at San Antonio, and Michael E. Carpenter, MS, RRT, Program Director, Respiratory Therapy Program, St. Philip's College. Correspondence may be directed to David C. Shelledy, PhD, RRT, Chairman, Department of Respiratory Care, The University of Texas Health Science Center at San Antonio, 7703 Floyd Curl Drive, San Antonio, TX 78284-7784.

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EXPLORING THE RELATIONSHIPS BETWEEN READING ABILITY AND CRTT EXAMINATION PERFORMANCE

Robert C. Shaw, Applied Measurement Professionals, and Steven J. Osterlind, University of Missouri-Columbia.

Abstract

A nationally representative sample (N = 281) from three distinct preparatory programs, whose ages ranged from 19-53 years, took a retired version of the CRTT examination and the Nelson Denny Reading Test (NDRT). We hypothesized that identifying, isolating, and understanding reading-related error factors could direct efforts to improve the measurement precision and performance on the CRTT examination. We used discriminant analysis to analyze the association between correctly responding to CRTT examination items and reading ability and to determine whether the number of words and syllable density could predict items possessing discriminant reading function. Using regression analysis, we examined overlapping variance between CRTT examination and NDRT total reading ability scores. With two-way ANOVA and MANOVA, we compared CRTT examination and NDRT score means among program and age groups. Discriminant analysis found that providing correct responses to 37 CRTT examination items was predicted ($p < .01$) by vocabulary scores (+VOCDISC). The 37 +VOCDISC items had stems with significantly ($p < .05$) higher mean syllable densities and fewer mean words. The 37 +VOCDISC CRTT examination items also provided significantly ($p < .05$) diminished contributions to the reliability of the CRTT examination. Younger (19-27 years) candidates and Technician program candidates had significantly ($p < .05$) lower mean CRTT examination and vocabulary scores. Encouraging lower syllable density and more context in item stems could diminish vocabulary-related error to a small degree. Programs training technician-level respiratory care candidates could probably improve their students' CRTT examination performance by considering reading ability as an admission criterion and emphasizing vocabulary building skills in their curriculum.

EXPLORING THE RELATIONSHIPS BETWEEN READING ABILITY AND CRTT EXAMINATION PERFORMANCE

Introduction

The certified respiratory therapy technician (CRTT) examination relies on responses to written questions that candidates must read to infer achievement of entry level. This does not seem remarkable. After all, paper and pencil examinations are routinely used throughout general and professional education curricula and in credentialing and licensing programs. However, what if some candidates were systematically prevented from completely understanding the questions? Would the process be considered fair? Would the test measure achievement as accurately as it could if candidates enjoyed more equal understanding of the questions before responding? These questions are rhetorically offered, but are important to consider as we begin exploring the relationships between reading and CRTT performance.

Fortunately, we were not the first to explore this area. Ironson, Homan, & Willis (1984) found that fourth graders with lagging reading abilities did less well on fourth grade math problems they were capable of answering when the items were written to their grade level. Therefore, it is possible that CRTT examination items may be written in such a way that those with lagging reading abilities may fail to fully understand and thus offer responses inconsistent with their underlying respiratory care ability. Inconsistent responses inflate measurement error. We already know that cognitive measures are less than perfectly precise. However, if we could identify a part of the source of imprecision, we could better direct efforts to avoid reading-related error.

The first study of reading difficulty associated with respiratory care textbooks was reported by Watson and Scully (1988). The following year, Chang (1989) attempted to measure the reading difficulty of the 100-item written examination for registered respiratory therapists (RRT). When he found that the average reading level of the examination was less than the level of textbooks he reviewed, Chang concluded that there was little chance that examinee performance would be effected by the difficulty of the text presented in the examination items.

However, Chang's methods weaken that assertion. Chang grouped the 100 items into 10 blocks of 10 items. His reading difficulty measures were derived from groups of items, not individual items. This misses the critical point. A test item is a self-contained entity. Responses to the item are not usually effected by surrounding items as they are intended to measure an isolated construct. Were an item to interact with lower ability readers in a way that engendered responses inconsistent with their respiratory care ability, Chang's technique would obscure the lack of understanding produced by one difficult to read item by lumping it with other benign items. Further, Chang's method ignored candidates' responses to the items entirely because item responses were not measured. He inferred how typical candidates would have responded based on the assumption that they first had to read textbooks apparently more difficult to read than groups of test items.

Also, while there are many uses for reading difficulty measures (Klare, 1987; Fry, 1987 & 1990), measuring the reading difficulty of a credentialing/licensing examination like the CRTT examination cannot be counted among them. In fact there is no generally accepted way to measure reading difficulty of text presented in testing situations (Klare, 1987; Fry, 1987). As Klare and Fry suggest, trying out text on the intended audience is the only way to definitively know how well they understand.

This is the approach we adopted for our study. To measure achievement of entry-level respiratory care abilities, we used a 140-item version of the CRTT examination retired after its use in the 1987 National Board for Respiratory Care (NBRC) validation study. Since then, the test specifications have changed as a result of a 1993 job analysis study. Certainly, there was substantial overlapping content before and after 1993, but it cannot be said that the CRTT examination used in this study reflected current practice in every way.

To measure reading abilities, we used the Nelson Denny Reading Test (NDRT). The NDRT is a commercially available examination that used a substantial standardization sample including subjects like those we intended to test (Brown et al., 1981). From the NDRT, sample subjects generated vocabulary (VOC), comprehension (COMP), and reading-rate (RATE) scores from 100 vocabulary items, 36 comprehension items and one reading rate measure. VOC and COMP subscores were mathematically combined (2 × COMP + VOC) to produce a TOTAL (TOT) score that could be compared to the NDRT table of norms to describe a candidate's reading grade level. However, we used the raw NDRT scores, not the transformed grade-level scores.

Prospectively Stated Null Hypotheses

Lacking evidence that entry-level candidates' reading abilities were related to CRTT examination scores, we limited our prospective hypotheses to null statements and then looked for evidence refuting those hypotheses.

1. VOC, COMP, and CRTT scores were not related to correctly answering CRTT items.
2. CRTT scores could not be predicted from TOT scores from program and age groups.
3. Mean CRTT, VOC, COMP, and RATE scores did not differ among program and age groups.

These last two hypotheses reflected our interest in the interaction between candidates' programmatic preparation and age, in addition to the straightforward relationship that might exist between reading ability and CRTT examination performance for the whole population.

Methods

Sampling

We created a database to sort all 460 accredited respiratory care programs by three levels of geographic region (eastern, central, and western states) and program type

(Technician; associate's degree, AS-Therapist; or bachelor's degree, BS-Therapist). Once sorted, we randomly selected nine sets of programs to solicit for the study. Program directors were asked to have students participate who were within three months of graduating. Testing began in March 1993 and continued through December 1993. Twenty education programs from 12 states participated in the study. By the conclusion of the testing phase, 282 usable exam score sheets were returned. This was 72.3% of the score sheets sent to participating programs. There was one CRTT examination outlier, so the sample size for data analysis was 281. Twelve subjects improperly completed the reading rate section of the NDRT. Therefore, analyses involving reading rate included 269 subjects.

Data Screening

Because of the planned statistical procedures, we had to take special care to meet the assumptions. A general guide describing the rational and methods of data screening while preparing to conduct analysis of behavioral factors has been recently offered in RESPIRATORY CARE (Shaw & Prewitt, 1995). Therefore, we need not belabor how we sought to ensure the variables were normally distributed, and that the variables shared linear relationships with one another. Also, because we planned to use two derivations of correlation, we sought to root out collinear relationships among potential predictors. Table 1 reveals that the RATE variable was normalized by square root transformation. Therefore, SqrtRATE was used in subsequent analyses involving reading rate. The remaining variables in Table 1 were used in raw form.

Table 1
Descriptive Statistics and Summary of Data Screening

Variable	*N*	Range	Mean	Median	*SD*	Skewdness	Kurtosis
CRTT[a]	281	60-139	102.4	102.0	14.69	-.020	-.023
VOC[a]	281	22-100	62.9	64.0	17.21	-.010	-.584
COMP[a]	281	4-36	25.1	26.0	5.79	-.545	-.002
RATE	269	74-472	238.5	232.0	72.73	.491	.352
SqrtRATE[b]	269	8.6-21.7	15.3	15.2	2.37	.000	.171

Note: [a]Original variable.
[b]Transformed variable.

Planned Analysis of the First Null Hypothesis

Satisfied by data screening that VOC, COMP, and CRTT were linearly related to one another, restating the first null hypothesis asked whether classifying subjects who provided a correct response to each CRTT item could be predicted by knowing their reading-ability scores (VOC and COMP). Such a question requires discriminant analysis. The hypothesis was posed 140 times for each CRTT item, with the attendant inflation in Type I error rate (Kirk, 1968; Leary & Mitchell, 1980) To counter this inflation, we adopted a more conservative α value (.01) to reject null hypotheses.

We made it still more difficult to reject null hypotheses regarding discriminant relationships between reading scores and providing correct responses to CRTT items by including CRTT total scores as a predictor variable with VOC and COMP. At first glance, the reader may think, because CRTT scores are composite expressions of the items answered correctly, there must be significant discriminant relationships between correctly answering CRTT items and CRTT scores. Generally, this is true. However, the purpose behind including CRTT scores as a discriminant predictor was to control for factors that CRTT scores and reading scores shared: the subjects' general intelligence, reasoning, and problem-solving and critical-thinking abilities. In order to reject a null hypothesis under these circumstances, VOC and COMP had to effect CRTT response variance independently of CRTT total scores. Therefore, the discriminant analysis results reflected unique reading prediction of subjects' responses to CRTT items. If VOC, COMP, and CRTT scores shared variance, then it was more difficult to reject null hypotheses. We omitted reading rate from this phase of analysis because data screening revealed that SqrtRATE had no significant correlation with CRTT scores and limiting the number of predictors increases the robustness of discriminant analysis.

Planned Analysis of the Second Null Hypothesis

While the first null hypothesis sought to find relationships between reading subscores and providing correct responses to CRTT examination items, the second hypothesis sought prediction of CRTT examination scores from NDRT TOT scores. By using multiple regression, we sought to find whether TOT scores and CRTT scores shared a significant degree of variance. We conducted regression analysis for the whole sample and for program and age groups. Therefore, we used an α value of .01 as a criterion to reject null hypotheses.

Planned Analysis of the Third Null Hypothesis

Because CRTT examination candidates were prepared in three distinct program types, we used program as a treatment variable along with age groups to compare group means for CRTT examination and NDRT scores. It is fair to ask why age groups were created when age data was continuously (Shaw & Prewitt, 1995) distributed in the sample. Data screening found that there were many more young subjects in the sample than older subjects, producing a positive skew that could not be normalized by transformation techniques. Therefore, ordinal (19-22 years, 23-27 years, 28-53 years) age groups were created to allow analyses of age using a linearly based model. We compared CRTT program and age group means by two-way ANOVA. Because the NDRT provided multiple dependent variables, we used two-way MANOVA to compare VOC and COMP program and age group means.

Our study was approved by our institutional review board and considered a minimal risk to the subjects. Still, informed consent was secured from all subjects prior to their participation. We used version 6.07 of SAS to analyze the data. (SAS Institute, Inc.; SAS Circle Box 8000; Cary, NC 27512-8000)

Results

Sampling

We originally intended to draw subjects from nine cells stratified by three geographic regions and three program types. Table 2 shows that we were not entirely successful in meeting that goal. Though the results of our study cannot generalize to Technician or BS-Therapist groups from the Western region, we were satisfied that the other cells were well enough represented to continue the study.

Table 2

Distribution of Subjects Across Regions and Program Types

			Region	
		East	Central	West
Program Type		(83) 29.6%	(142) 50.5%	(56) 19.9%
Technician[a]	(105) 37.4%	(30) 10.7%	(75) 26.7%	(0) 0.0%
AS-Therapist[b]	(114) 40.6%	(33) 11.7%	(25) 8.9%	(56) 19.9%
BS-Therapist[c]	(62) 22.0%	(20) 7.1%	(42) 14.9%	(0) 0.0%

Note: [a]Certified respiratory therapy technician.
[b]Associate's degree therapist program.
[c]Bachelor's degree therapist program.

Reliability Analysis

Table 3 shows the reliability coefficients for CRTT examination and NDRT scores. Without reliable measures of entry-level respiratory care and reading abilities, the analysis could not continue. We found the scores satisfactorily reliable. Coupling the reliability results with the normally distributed CRTT examination and NDRT scores shown in Table 1, we concluded that our sample was a nonhomogeneous, normally variable group that generally represented the population of entry-level candidates. The reliability and descriptive data for CRTT examination and NDRT scores particularly encouraged us to continue the study in spite of the deficiencies in western region programs.

Table 3
Kuder-Richardson (KR-20) Reliability Coefficients for Certified Respiratory Therapist Technician (CRTT) Examination and Nelson Denny Reading Test (NDRT) Scores

Test	KR-20	SEM	95% CI
NDRT Vocabulary subtest	.948	3.92	7.68
NDRT Comprehension subtest	.807	2.54	4.98
CRTT Examination	.893	4.81	9.43

Note: SEM is the standard error of the mean; CI is the confidence interval.

CRTT Item Analysis

Producing a correct response to CRTT examination items could be discriminantly predicted ($p < .01$) by COMP scores (+COMPDISC) for 31 items and by VOC scores (+VOCDISC) for 37 items. Six of these items overlapped. This left 61 CRTT items with an apparent discriminant relationship with at least one reading factor (and potential contributors to reading-related measurement error).

CRU Multiple Regression Analysis

For the whole sample, TOT regression offered significant ($R^2 = .08$, $p < .0001$, SEE = 14.1), though weak prediction of CRTT examination scores. As Table 4 shows, TOT regressions for Technician program and 19- to 22-year-old subjects were stronger. For candidates from Technician programs, nearly one quarter of CRTT score variance was predicted by TOT. By inserting the CRTT cut score of 98 into the equation, we found that Technician candidates who achieved a TOT score of at least 106 had a reasonable probability of passing the CRTT examination. The 19- to 22-year-old subjects also demonstrated a moderate degree of CRTT score prediction from TOT scores. The 28- to 53-year-old subjects also demonstrated significant CRTT score prediction from TOT scores, but the degree of explanation was less than half that shown by the 19- to 22-year-olds and the Technician program subjects.

Table 4
Significant Regression Equations for Program and Age Groups

Group Analysis	Regression Equation	R^2	TOT Cut	TOT Cut 95% CI
Technicians	CRTT = 69.739 + TOT (.266)	.22*	106	81-132
19-22 year olds	CRTT = 69.432 + TOT (.295)	.18*	97	71-123
28-53 year olds	CRTT = 88.464 + TOT (.142)	.09*	67	39-95

Note: The therapist program group and the 23- to 27-year-old group did not show significant relationships between reading ability and certified respiratory therapy technician examination score (CRTT). TOT is the Nelson Denny examination total score, and CI is the confidence interval. *$p < .005$

Program and Age Group Mean Comparisons

Table 5 shows that Technician program and younger subjects had significantly lower mean CRTT scores than the other groups. The F value (2.03) for the program × age group interaction approached significance (p = .0905, df 4,261). Because the error term of the interaction analysis was inflated by small cell sizes within the two older BS-Therapist age groups and because of the positive regression finding for Technician program and 19- to 22-year-old subjects, we plotted the interaction means in Figure 1. In the figure, three program × age groups had mean scores below the CRTT cut score. However, post-hoc one-way ANOVAs found that only the two younger Technician program groups had means systematically lower than their 28- to 53-year-old age group counterpart whose mean score was above the CRTT cut. Although Figure 1 places the 23- to 27-year-old BS-Therapist program group below the CRTT cut, the small size of the two older BS-Therapist groups diminished the power of the ANOVA such that we saw an insignificant mean comparison.

Table 5
Comparing Certified Respiratory Therapist Technician Score Means among Program and Age Groups

Two-way ANOVA Model $F = 4.23$, df (8,261), $p < .0001$

Group	*N*	Mean (*SD*)	*F*	df	*p*
Technician	104	98.3 (14.8) B	7.91	2,261	.0005
AS-Therapist	105	106.0 (14.5) A			
BS-Therapist	61	103.6 (13.9) A			
19-22 year olds	98	99.1 (15.5) A	4.92	2,261	.008
23-27 year olds	69	101.8 (15.4) A			
28-53 year olds	103	105.5 (13.2) B			

Note: After Fisher's LSD test, means with the same letter were not significantly (.05) different. Technician is certified respiratory therapy technician; AS-Therapist is associate's degree therapist program; BS-Therapist is bachelor's degree therapist program.

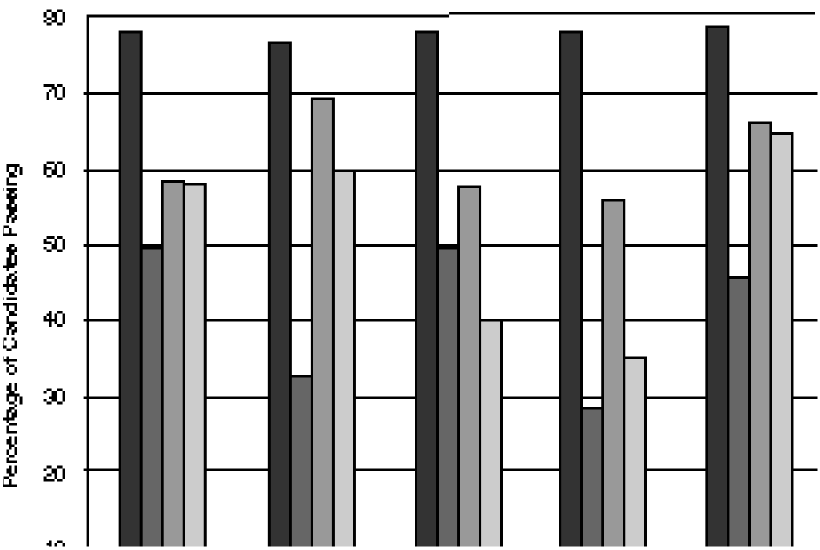

Figure 1. Age group mean comparisons among program groups
T = technician program; A = associate's degree therapist program; and B = bachelor's degree therapist program.
**p < .005.

Table 6 compares mean reading subscores among program and age groups. Technician program subjects had significantly lower VOC and SqrtRATE scores and BS-Therapists had significantly higher COMP scores. The 19- to 22-year-old group had significantly lower VOC scores. The interaction of program × age groups on reading scores was insignificant (p = .8045, F = 0.41, df 4,261).

Table 6
Comparing Reading Score Means (SD) among Program and Age Groups

Two-way MANOVA Model F = 5.94, df (8,261), p < .0001

	Technicians N = 104	AS-Therapists 105	BS-Therapists 61	F	df	p
VOC	59.1 (17.5) B	66.4 (17.3) A	62.7 (15.7) AB	5.23	2,261	.0059
COMP	24.2 (5.7) B	25.1 (6.0) B	26.9 (5.2) A	4.32	2,261	.0143
SqrtRATE	14.6 (2.6) B	15.6 (2.3) A	15.7 (2.1) A	5.70	2,249	.0038
	19-22 years N = 98	23-27 years 69	28-53 years 103	F	df	p
VOC	58.9 (14.2) B	57.6 (15.4) B	69.9 (18.7) A	17.58	2,261	.0001
COMP	25.7 (5.4)	24.1 (6.4)	25.3 (5.6)	1.10	2,261	.3337
SqrtRATE	15.2 (2.4)	14.9 (2.4)	15.5 (2.3)	2.08	2,249	.1270

Note: After Fisher's LSD test, means with the same letter were not significantly (.05) different. Technician is certified respiratory therapy technician; AS-Therapist is associate's degree therapist program; BS-Therapist is bachelor's degree therapist program.

Post-Hoc Item Reading Predictor Analysis

Given the relationships demonstrated thus far between reading and CRTT scores, we engaged post-hoc analyses to identify CRTT item characteristics associated with reading-related error. Our first prospective null hypothesis and subsequent item analysis found two groups of items with +VOCDISC and +COMPDISC relationships. Responding correctly to these two groups of CRTT items could be discriminantly predicted with our subjects' VOC or COMP scores. The first post-hoc question then became: Can we predict membership in +VOCDISC and +COMPDISC item groups by the difficulty of the text presented in the items? Because reading difficulty measures typically used word and syllable counts (Rakow & Gee, 1987; Rush 1985), we explored whether word, syllable and syllable density (syllables/words) counts from CRTT item stems, and options could predict membership in the +VOCDISC and +COMPDISC item classes. Predicting

+VOCDISC and +COMPDISC item classifications required discriminant analysis with six predictor variables: stem words, stem syllables, stem syllables per word, option words, option syllables, and option syllables per word. We used the backward elimination option of discriminant analysis to test the first post-hoc null hypothesis: Stem and option words, syllables, and syllable densities did not predict +VOCDISC and +COMPDISC item classifications.

Several of the potential predictors were abnormally distributed and required transformations (Shaw & Prewitt, 1995) to achieve normality. Only stem syllables per word (SSPW) could be used in its raw form, the other transformed, potential discriminant predictors were: log of stem words (LogSW), log of stem syllables (LogSS), log of option words (LogOW), square root of option syllables (SqrtOS), and log of option syllables per word (LogOSPW). The advantage of simultaneously analyzing all predictors was that Type-I error remained fixed at the .05 level (Leary & Mitchell, 1980).

As a derivative of correlation, discriminant analysis is sensitive to collinear (Shaw & Prewitt, 1995) predictors. SAS offers a feature within discriminant analysis that allowed us to screen out collinear variables ($R \geq .70$) while running the analysis. We also imposed a significance level of ≤ .10 to eliminate extraneous variables. Therefore, we were able to narrow the scope of exploration to only those predictors that were important to the +VOCDISC and +COMPDISC classifications. Redundant and insignificant predictors were eliminated with one procedure.

Post-Hoc Item Reading Difficulty Results

Addressing COMPDISC first, LogSW, SSPW, LogOW, and LogOSPW survived the two tolerance tests we set in the discriminant procedure. LogSS and LogOS were eliminated by the collinearity criterion. The 31 CRTT items possessing discriminant relationships with COMP scores formed one item class (+COMPDISC) while the remaining items formed the other class (ØCOMPDISC). Backward elimination discriminant analysis removed all four predictors from the model. The lowest *p* value among the four predictors was .41. Therefore, the analysis found there were no word or syllable density counts that reliably predicted membership in the +COMPDISC item group.

The 37 items with the +VOCDISC classification formed one group (+VOCDISC) while the remaining items formed the other group (ØVOCDISC). Again, LogSW, SSPW, LogOW and LogOSPW survived the collinearity tolerance test and were included in the analysis. From Table 7, both of the factors involving item options eventually dropped out, leaving two significant item stem factors. At the end of the backward elimination procedure, LogSW had a Partial $R^2 = .05$ ($p = .0104$; $F = 6.752$; df 2,137;) and SSPW had a Partial $R^2 = .04$ ($p = .0140$; $F = 6.193$; df 2,137).

Table 7
Backward Elimination Discriminant Analysis of VOCDISC Classification—Step 1

Item Component	Reading Difficulty Factors	Partial R^2	F	p
Stem	LogSW	.0397	5.577	.0196
	SSPW	.0425	5.998	.0156
Options	LogOW	.0013	0.179	.6725
	LogOSPW	.0025	0.339	.5614

Note: LogSW is log of stem syllables per word; SSPW is stem syllables per word; LogOW is log of option words; and LogOSPW is log of option syllables per word.

We used discriminant analysis to highlight sources of difficult vocabulary that seemed associated with responding correctly to CRTT items. Our focus was now set on the number of words presented in the CRTT item stems and the syllable density of the words used in the stems. To learn whether difficult vocabulary found in the +VOCDISC item group was directly or indirectly related to stem words and syllable density, we ran ANOVA procedures using +VOCDISC and ØVOCDISC as the independent variables. LogSW and SSPW were the dependent variables. Because the ANOVAs were merely confirmatory tests of null hypotheses rejected by discriminant analysis, we were comfortable setting our α value at .05.

Table 8 shows that the 37 items in the +VOCDISC group, had significantly higher mean syllable density, yet fewer mean words in the stems. The third dependent variable in Table 8, Zr_{pb}, was a Z-score transformation of the traditional point-biserial correlation commonly used by psychometricians to describe the degree of consistency between responding correctly to an item and candidates' total scores. With this final analysis, we wanted to see if the item responses were positively influenced by vocabulary ability would also encourage responses inconsistent with respiratory care ability. If so, then this group, +VOCDISC items, would have a lower mean point-biserial value. The Z-score transformation was necessary because it is not possible to directly compare point-biserial values with inferential statistics because point-biserials are correlation derivatives.

Because transformation obscured the magnitude of the mean differences for stem words and the point-biserial values, we also show the raw means for the VOCDISC groups in Table 8. Therefore, in addition to averaging two syllables per word, the +VOCDISC group of items tended to have seven fewer words and an average point-biserial value .036 points below the ØVOCDISC group.

Table 8
Comparing SSPW, LogSW and Zr_{pb} Means (SD) between VOCDISC Item Classes

Variables	ØVOCDISC 103-Item Group	+VOCDISC 37-Item Group	*F*	df	*p*
SSPW	1.89 (.29)	2.00 (.22)	4.89	1,138	.0287
LogSW	3.38 (.47)	3.17 (.45)	5.44	1,138	.0211
Stem Words	33.00	26.00			
Zr_{pb}	0.264 (.09)	0.226 (.10)	4.36	1,138	.0387
Point-Biserial	0.258	0.222			

Note: SSPW is the stem syllables per word; LogSW is the log of stem words; and Zr_{pb} is the *z*-scale equivalent for the point-biserial correlation (r_{pb}); ØVOCDISC is the item group for which the discriminant analysis null hypothesis for vocabulary scores was accepted; and +VOCDISC is the item group for which the discriminant analysis null hypothesis for vocabulary scores was rejected.

Discussion

We compared mean point-biserial values for the +VOCDISC and ØVOCDISC groups because correctly responding to the 37 items in the +VOCDISC group could be predicted to a significant degree by the subjects' vocabulary scores. These items systematically presented fewer words and higher syllable densities to the subjects. We wondered if these same items would show less consistency with CRTT total scores given the apparent vocabulary-related error associated with responses to these items. Table 8 indicates that sources of vocabulary-related error introduced by CRTT items were associated with more total score inconsistency. The significantly lower mean point-biserial value for the 37 items in the +VOCDISC group meant that the items contributed systematically less to the reliability of the CRTT examination. The fact that these same items had significant vocabulary factors affecting responses was very probably not a coincidence, although the most we can say is that the findings in Table 8 are associated with one another. We cannot say that fewer stem words and higher syllable densities cause reduced reliability because of the methods and statistics we used.

This brought us back to where we began the study. We first inquired if there was reading-related error associated with CRTT scores. In the process, we also found that vocabulary factors seemed to affect CRTT scores for 19- to 27-year-olds and candidates from Technician programs. Although our data does not definitively show evidence of a program × age group interaction, we were unwilling to rule out that possibility. The source of this relationship seemed to come from CRTT items that presented more difficult to read, polysyllabic words embedded in shorter item stems. We assert that by presenting little surrounding context with syllable intense words, younger candidates and Technician program candidates may have been prevented from fully understanding the questions. There is evidence that +VOCDISC item responses were slightly inconsistent with respiratory care abilities and thus, we saw that +VOCDISC group contribution to CRTT score reliability was slightly diminished.

Having identified this source of vocabulary-related error, NBRC item writers and reviewers could take steps to diminish the affect vocabulary has on CRTT scores. Particularly holding down syllable density and increasing the context offered in CRTT item stems would help make CRTT items more universally understood by the candidates taking the examination.

In spite of the apparently interrelated evidence, we found linking difficult vocabulary to diminished CRTT score reliability, the magnitude of vocabulary-related error is small compared to the general precision of CRTT scores. We found a reliability coefficient of .89 which implies that 89% of CRTT score variance was attributed to candidates' respiratory care abilities. The NBRC CRTT examination committee met its burden to produce an exam that was acceptably reliable. Granted, the examination we used is now nearly a decade old, but speculation about the current state of CRTT score reliability must acknowledge that historically about 2,000 candidates take each form of the examination which encourages normal variation in the score distribution. The candidates continue to have widely variable backgrounds and training. The NBRC continues to generate and review items in the same manner. Therefore, we cannot identify any new opportunities for CRTT score reliability to diminish in the current forms.

We initially approached this study strictly from a measurement error perspective. However, as we shared the results with interested persons, the question they consistently raised asked whether candidates' programs have met their burden preparing candidates to take the CRTT examination. Our findings particularly should compel Technician programs to review admission criteria. Admitting younger students without screening reading abilities or offering vocabulary building in the curriculum could set students up to be failing CRTT candidates. If Technician programs were interested in this kind of screening and satisfied that our sample was drawn from a geographically diverse population such that the results would generalize to their students, then the regression equations and NDRT total score cuts we present in Table 4 could be used for their program.

However, if Technician programs seriously wanted to screen candidates, they should rely on more than NDRT scores. Table 4 shows wide 95% confidence interval ranges around predicted TOT CUTS which means that there is a good deal of error using NDRT TOT alone to predict CRTT scores. The real utility of NDRT TOT scores would likely be as one of several predictor variables in a multiple regression model. Other predictors could include high school academic performance measures, such as grade point average or class rank, and college entrance examinations (e.g., ACT or SAT).

Are 23- to 27-year-old BS-Therapists also at risk? Figure 1 might suggest so, except the mean CRTT score for the group was based only on 10 subjects from which we are unwilling to generalize. Their mean CRTT score was statistically indistinguishable from the younger and older groups of BS-Therapists with means above the CRTT cut score. Therefore, the fact these 10 subjects had a CRTT mean below the cut, may have been an aberration, or we may have lacked the statistical power to find a true difference because of uneven group sizes. This is an area that deserves more attention. However, it may be logistically difficult to find a critical mass of older BS-Therapists candidates to study because Figure 1 also suggests that older students tend to select Technician or AS-Therapist programs.

Before considering changing examination development methods or program curricula, one must first be satisfied that the evidence presented here was generated from a generalizable source. Our findings are delimited by not securing any volunteers from Technician or BS-Therapist programs from the western region. In spite of that loss, our important study variables—CRTT, VOC, and COMP scores—were normally distributed. Normally distributed data does not just happen. Understanding that physical and cognitive abilities are normally distributed in the population led us to conclude that we had adequately sampled the population, even if that population did not include some programs from the Western region.

Table 6 shows the only rejected null hypothesis concerning reading rate. In addition to having significantly lower VOC and COMP scores, Technician program candidates had significantly lower reading rates. However, we found that reading rates and CRTT scores were unrelated. Even the slowest readers seemed to have adequate time to complete the examination. Therefore, the three hours currently allowed to take the CRTT examination seems sufficient according to this evidence.

Conclusions

Conclusions with substantial supporting evidence are that (1) responses to CRTT items could be made less susceptible to vocabulary-related error by limiting high syllable density words in the item stems and assuring sufficient context for the questions, (2) Technician programs should consider screening the youngest admission candidates' reading abilities and incorporate vocabulary building into their curriculum.

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Authors' Note

Robert C. Shaw, PhD, RRT, is Program Director, Lenexa, Kansas; and Steven J. Osterlind, PhD, is Professor, Education and Counseling Psychology, Columbia, Missouri.

Correspondence regarding this article should be addressed to Robert C. Shaw, PhD, RRT, Program Director, Applied Measurement Professionals, 8310 Nieman Road, Lenexa, Kansas, 66214.

NOTES

Notes

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