Critical Issues in Dental Education

Predictive Validity of Critical Thinking Skills for Initial Clinical Dental Hygiene Performance


Abstract: This study collected validity evidence on the utility of critical thinking skills and critical thinking disposition in predicting initial clinical performance. The predictive value of critical thinking skills scores and disposition scores was examined to determine their unique contribution beyond that provided by traditional predictors: grade point average, age, and number of college hours. The study involved three phases: establishing content validity of three outcome measures; assessing students’ baseline critical thinking skills and disposition using the California Critical Thinking Skills Test (CCTST) and the California Critical Thinking Dispositions Inventory (CCTDI); and assessing students’ initial clinical competence, clinical reasoning, and clinical knowledge. All baccalaureate-level dental hygiene programs in the United States affiliated with a dental school (N=22) were invited to participate; of those, seven volunteered. A convenience sample of 207 first-year dental hygiene students was obtained. A series of hierarchical multiple regression analyses demonstrated that CCTST scores explained a statistically significant (p<.05) proportion of variance in students’ initial clinical reasoning scores, acquired knowledge scores, and faculty ratings, above and beyond that explained by other predictor variables. CCTDI scores were not significant predictors of any outcome measure. It was concluded that CCTST is a good predictor of initial student outcomes and may have utility for student selection and retention.

Dr. Williams is Professor, Department of Dental Public Health and Behavioral Science, University of Missouri-Kansas City; Dr. Glasnapp is Professor, Department of Education, University of Kansas; Ms. Tilliss is Professor, Department of Dental Hygiene, University of Colorado; Ms. Osborn is Associate Professor, Department of Dental Hygiene, University of Minnesota; Ms. Wilkins is Assistant Professor and Chair, Department of Dental Hygiene, Loma Linda University; Ms. Mitchell is Former Faculty, Department of Dental Hygiene, University of North Carolina; Ms. Kershbaum is Professor, Department of Dental Hygiene, University of Michigan; and Ms. Schmidt is Manager, Dental Hygiene Education, Commission on Dental Accreditation. Direct correspondence and requests for reprints to Dr. Karen Williams, UMKC School of Dentistry, 650 E. 25th Street, Kansas City, MO 64108; 816-235-2058 phone; 816-235-5472 fax; williamsk@umkc.edu.

Submitted for publication 6/17/03; accepted 9/10/03

Criticalism about the current model of dental and allied dental education has sparked an interest in the development of critical thinking skills in students. Recommendations from the Institute of Medicine (IOM) regarding the need to increase students’ critical thinking abilities in order to better transfer scientific knowledge and thinking to clinical decisionmaking have also helped bring the issue of critical thinking in dental education to the forefront.

Allied dental education has traditionally utilized a teacher-centered, lecture-based educational approach, along with a performance-based approach to clinical activities. Several researchers have criticized this approach as encouraging superficial learning aimed at rote recall for testing purposes rather than clinical reasoning. Those authors suggest that this style of instruction can result in discrete, isolated “hard” knowledge or actions that do not encourage applying critical thinking to the clinical environment. The need to support development of transferable knowledge in the curriculum by improving educational strategies beyond traditional techniques continues to be stressed. The recently approved competencies for entry into dental hygiene highlight the need for dental hygienists to be effective critical thinkers. In spite of a consensus on the need to develop good critical thinkers in allied dental education, implementation of critical thinking strategies to encourage good clinical judgment is limited. However, dental hygiene education does focus on teaching students a methodical process for approaching patient care termed the “dental hygiene process of care.”

The dental hygiene process of care has been favorably compared to the nursing process of care. It is a process of clinical reasoning and decision-making based on an assessment of clinical parameters, determination of the patient’s problems and/or needs, development of a plan for care, implementation of treatment, and subsequent evaluation of patient outcomes. Clinical reasoning has been characterized as a complex and often unconscious integration of critical thinking and data-collecting procedures aimed at patient care. Critical thinking is subsumed in the clinical reasoning process in that clinicians must analyze information, use inductive and deductive reasoning to determine diagnoses, establish and prioritize patient care plans, and make inferences and reach conclusions on the basis of available information in order to increase the probability of a desirable outcome.

Although students begin to use the dental hygiene process of care at the conclusion of the preclinical curriculum, the intensive nature of the first semester course work generally precludes direct teaching of critical thinking and clinical reasoning skills. However, anecdotal evidence suggests that many preclinical faculty are able to identify those students who can and cannot use the “process of care” effectively based on their preexisting reasoning skills. While no studies to date have examined the premise that general critical thinking skills might be related to initial success in dental hygiene, research examining the relationship between critical thinking skills and preclinical and clinical success in nursing and medicine has demonstrated a positive relationship between them exists. Moreover, Chambers demonstrated the predictive validity of preclinical instructors’ judgment for later clinical performance and students’ failure to complete the educational program in dentistry in a normal time line. This finding suggests that faculty judgment is a valid means to assess student factors such as clinical reasoning.

Several authors have suggested that assessing health professions students’ entry-level critical thinking skills would be useful as a predictor of performance, as well as a possible screening mechanism to identify students with immature critical thinking ability in order to individualize meaningful educational strategies. Literature on the predictive validity of traditional admissions criteria suggests limited utility for cognitive measures such as standardized tests, previous total grade point average (GPA), and science GPA as they relate to clinical judgment and performance in clinical care. Because of these limitations, there has been increasing interest in assessing other measures as predictors of student achievement. Studies across different age groups and academic disciplines suggest that metacognitive measures such as motivation, self-efficacy, self-monitoring, disposition, and other affective measures may also have utility in predicting student performance.

The nursing and medical education literature suggests that preexisting critical thinking ability may be an important predictor of student success and clinical judgment. Given that sufficient time and/or strategies are not available to effectively teach the critical thinking skills thought necessary to making appropriate clinical judgments, an alternative is to require that students possess these skills at a sufficient level upon entry into the program. To date, no studies in the dental education literature have examined the predictive validity of critical thinking skills and disposition for critical thinking for early clinical judgment of dental hygiene students. Therefore, this study was undertaken to collect validity evidence addressing the utility of critical thinking skills and critical thinking disposition assessments in predicting early clinical performance in a sample of first-year dental hygiene students enrolled in baccalaureate programs. The primary research question of interest was the degree to which students’ pre-existing critical thinking skills and critical thinking disposition uniquely predict early clinical reasoning ability.

Methods

The study was conducted across three phases. During phase one, criterion measures were defined, developed, and refined using a panel of experts in the field of initial (first-year) preclinical and clinical dental hygiene. The second phase focused on securing participation of institutions to provide the desired number of students and collecting data on the predictor variables: students’ age; number of college hours completed; entering GPA; and baseline critical thinking skills and disposition. In the third phase, data on three criterion measures (faculty rating of student performance/competency; objective test of clinical problem-solving and judgment examination;
and preclinical knowledge acquisition) were collected from all participants. In addition, the critical thinking and disposition measures were administered to all participants four weeks into the second semester of the first year to control for the potential change in scores over the semester that might impact criterion measures.

**Measures**

During the first phase of the study, a panel of preclinical content experts was used to establish the content validity of a faculty rating scale for assessing initial clinical reasoning and to refine the currently released case-based pilot National Board Dental Hygiene Exam (NBDHE) for use in assessing preclinical judgment and acquired knowledge. Experts were selected from a national sample of educators who responded to an advertisement in the newsletter of the American Dental Education Association’s Section on Dental Hygiene Education. Twelve full-time faculty representing institutions across the nation volunteered to participate.

The content of the faculty rating scale was developed based on objectives obtained from the preclinical syllabi from the panel members’ institutions. All objectives that related to initial dental hygiene process of care were placed on separate cards and a comprehensive set of cards distributed to each panel member. Judges categorized each objective by identifying the process of care domain it was intended to assess. Those objectives that did not correspond to a process of care category, as determined by an agreement of 75 percent of the judges, were eliminated. The retained objectives within each process of care domain were then used to develop the infrastructure for a faculty rating scale through an iterative consensus building process. The final instrument with operationalized categories is shown in Figure 1. Likert-type responses for the rating scale were adopted from those proposed by Sorrell et al. for the University of North Carolina Greensboro Critical Thinking Skills Evaluation Instrument.33

The pilot case-based portion of the NBDHE served as the basis for the clinical judgment outcome measure. Again, the expert panel judged which questions corresponded to the learning objectives from the collected preclinical syllabus, and those questions were retained to construct a reduced form of the test. The panel then judged each item and independently estimated the percentage of marginal students they believe would successfully complete each item. Items were eliminated if 75 percent or more members of the panel estimated item difficulty as less than 30 percent. Twenty-two items relating to six separate patient cases were deemed appropriate for assessing the initial clinical reasoning of students.

A similar strategy was used to extract a knowledge-based outcome measure from the NBDHE. Again, the panel assessed questions as they related to educational objectives from the syllabi and identical criteria for consensus used to identify knowledge questions. A fifteen-item test was determined by the panel to have face validity for student knowledge at that level of development.

**Sample**

All baccalaureate-level, accredited, dental hygiene programs in the United States affiliated with a dental school (N=22) were invited to participate. Participating institutions were limited to baccalaureate programs in dental schools to control for potential confounding variables of different curricula and preprofessional education.12,19,34 Seven institutions agreed to participate, and a site coordinator was recruited from each site to maintain continuity of procedures throughout the study. Site coordinators met to be calibrated in study implementation and administration of outcome measures. Over the two-day training session, procedures to standardize administration of the measures were discussed, and coordinators were trained in using the Faculty Rating Scale to reduce measurement error between sites.

Institutional Review Committee approval was obtained from all participating institutions. A convenience sample of 207 first-year dental hygiene students was then recruited from the following institutions: University of Colorado Health Sciences Center, University of North Carolina, University of Missouri-Kansas City, University of Mississippi, University of Minnesota, University of Michigan, and Loma Linda University. All participants were given a thorough description of the study and signed consent forms.

**Data Collection**

The California Critical Thinking Skills Test (CCTST) and the California Critical Thinking Dispositions Inventory (CCTDI) were administered to participants during the first week of entry into the dental hygiene program and again four weeks into the second semester of their first year. Total scores
for each of the measures were computed for each administration. The CCTST and CCTDI are both standardized, norm-referenced tests that assess the core critical thinking skills and core critical thinking dispositions.\textsuperscript{35,36} The CCTST reports a total score based on analysis, inference, evaluation, inductive reasoning, and deductive reasoning. The CCTDI assesses seven dispositional subscales: inquisitiveness, organization of inquiry, value of reason, truth-seeking, open-mindedness, self-confidence, and maturity. These instruments were selected as they are based on the American Philosophical Association’s consensus definition of critical thinking and more closely reflect the skills required in clinical reasoning.\textsuperscript{15,17-19,35}

Program directors provided the following data for each participant: entering GPA, total college hours at entry, and students’ age. Data were coded to ensure anonymity while concomitantly allowing for matching of data. No interventions were imposed; participants completed each respective institution’s preclinical phase without modification.

Four weeks following completion of the preclinical phase of the curriculum, supervising clinical faculty completed the faculty rating form for each student participant. This time frame for final data collection was selected to avoid measuring student outcomes during final exams. This schedule also permitted a one-month “clinical practice” phase during which students used skills learned in the preclini-

---

**Figure 1. Initial clinical competency evaluation instrument**

Student ID __________________________ Date ______________________________

Evaluator____________________________

Rating Scale:

5 = Functions independently
4 = Requires minimal guidance
3 = Requires frequent guidance
2 = Requires consistent guidance
1 = Cannot perform even with guidance

1. **Professionalism and communication**
   Student demonstrates positive nonverbal, verbal, and appropriate written communications, respects autonomy of individuals, and displays professionalism with patients, peers, and faculty.

2. **Disease prevention and health promotion**
   Student uses appropriate methods to ensure the health and safety of the patient and dental hygienist in the delivery of care, including infection control and emergency methods.

3. **Patient assessment**
   Student systematically collects, contrasts to normal values, and records data on the general and oral health status of patients using methods consistent with medicolegal principles.

4. **Patient diagnosis**
   Student identifies patient needs, health conditions, and/or medications that impact the delivery of dental hygiene services and obtains consultations as indicated.

5. **Appointment and patient care planning**
   Student collaborates with patient and other health professionals to formulate an appointment plan and comprehensive, patient-centered dental hygiene care plan.

6. **Implementation of care**
   Student provides basic dental hygiene treatment that includes preventive and therapeutic services designed to achieve oral health goals formulated through collaboration with patient and faculty.

7. **Evaluation**
   Student discusses and provides a rationale for the evaluation process as it relates to clinical, preventive, and educational services and develops an appropriate timeframe for patient evaluation in collaboration with faculty.
cal course work. Site coordinators met with the supervising faculty to ensure standardized interpretation of rating categories. During the same period, the reduced forms of the case-based NBDHE and knowledge-based NBDHE were administered to students in order to assess their initial clinical reasoning and acquired knowledge. Additionally, the CCTST and CCTDI were administered four weeks into the second semester of the first year to evaluate potential change in general critical thinking skills and critical thinking disposition.

**Data Analyses**

Several analyses were used to examine the data. Descriptive analyses characterized baseline data for students at each of the participating institutions. Correlations among predictor variables and outcome variables were examined to determine the degree of relationship among measures.

To assess the primary hypothesis—“To what degree do students’ pre-existing critical thinking skills and critical thinking disposition uniquely predict first-year clinical reasoning ability?”—a series of hierarchical multiple regression analyses were used to examine the additional explained variance by the CCTST and CCTDI beyond that explained by traditional measures of incoming GPA, age, and total college credit hours on faculty rating of students, acquired knowledge, and clinical reasoning. Additionally, a second set of hierarchical multiple regression analyses were conducted such that acquired knowledge was used as a predictor variable along with the other predictor variables to control for the effect of learning during the study period on the criterion measures of clinical reasoning and faculty rating of student competence.

**Results**

Baseline data on age, entering GPA, number of college credit hours at program entry, CCTST, and CCTDI total scores are displayed in Table 1. Overall, participants ranged in age from nineteen to fifty-five with a mean age of twenty-four ($\pm 5.1$) years and were relatively comparable among institutions. Entering GPA for all participants ranged from 2.02 to 3.96, with an overall mean GPA of $3.17 (\pm 0.39)$. Entering GPA for each institution varied from a low of 2.83 to a high of 3.42.

The mean number of entering college credit hours for all participating students was 74.57 ($\pm 32.38$). Large standard deviations for each institution show that there was wide variability in academic preparation prior to entry into dental hygiene, without regard to institutional affiliation.

<table>
<thead>
<tr>
<th>Institution</th>
<th>Age Mean</th>
<th>GPA Mean</th>
<th>Credit Hours Mean</th>
<th>CCTST Initial Mean</th>
<th>CCTST Second Mean</th>
<th>CCTDI Initial Mean</th>
<th>CCTDI Second Mean</th>
<th>Faculty Rating Mean</th>
<th>Clinical Reason Mean</th>
<th>Acquired Knowledge Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institution 1</td>
<td>22.8</td>
<td>3.23</td>
<td>81.78</td>
<td>13.17</td>
<td>300.70</td>
<td>13.57</td>
<td>294.05</td>
<td>3.16</td>
<td>54.05</td>
<td>57.21</td>
</tr>
<tr>
<td>N=22</td>
<td>S.D. 2.9</td>
<td>0.26</td>
<td>28.75</td>
<td>4.41</td>
<td>25.59</td>
<td>4.86</td>
<td>30.68</td>
<td>0.86</td>
<td>13.59</td>
<td>12.35</td>
</tr>
<tr>
<td>Institution 2</td>
<td>25.6</td>
<td>3.42</td>
<td>89.25</td>
<td>15.10</td>
<td>303.15</td>
<td>16.06</td>
<td>285.50</td>
<td>4.07</td>
<td>70.21</td>
<td>70.21</td>
</tr>
<tr>
<td>N=20</td>
<td>S.D. 5.7</td>
<td>0.35</td>
<td>31.24</td>
<td>3.57</td>
<td>31.04</td>
<td>3.73</td>
<td>16.06</td>
<td>0.68</td>
<td>7.91</td>
<td>15.91</td>
</tr>
<tr>
<td>Institution 3</td>
<td>24.4</td>
<td>2.83</td>
<td>61.38</td>
<td>14.88</td>
<td>307.76</td>
<td>15.64</td>
<td>298.11</td>
<td>3.08</td>
<td>55.50</td>
<td>59.00</td>
</tr>
<tr>
<td>N=33</td>
<td>S.D. 4.8</td>
<td>0.41</td>
<td>23.72</td>
<td>3.71</td>
<td>30.93</td>
<td>4.30</td>
<td>15.64</td>
<td>0.66</td>
<td>13.52</td>
<td>10.60</td>
</tr>
<tr>
<td>Institution 4</td>
<td>22.0</td>
<td>3.12</td>
<td>87.92</td>
<td>14.27</td>
<td>301.83</td>
<td>14.98</td>
<td>294.28</td>
<td>3.41</td>
<td>46.55</td>
<td>54.66</td>
</tr>
<tr>
<td>N=30</td>
<td>S.D. 4.0</td>
<td>0.34</td>
<td>40.31</td>
<td>4.35</td>
<td>26.86</td>
<td>4.11</td>
<td>30.59</td>
<td>0.47</td>
<td>10.17</td>
<td>9.63</td>
</tr>
<tr>
<td>Institution 5</td>
<td>25.0</td>
<td>3.32</td>
<td>72.70</td>
<td>14.90</td>
<td>294.41</td>
<td>15.51</td>
<td>291.44</td>
<td>2.97</td>
<td>50.70</td>
<td>59.62</td>
</tr>
<tr>
<td>N=38</td>
<td>S.D. 5.7</td>
<td>0.30</td>
<td>32.30</td>
<td>4.00</td>
<td>26.26</td>
<td>4.31</td>
<td>26.27</td>
<td>0.72</td>
<td>8.78</td>
<td>13.62</td>
</tr>
<tr>
<td>Institution 6</td>
<td>23.2</td>
<td>3.15</td>
<td>61.29</td>
<td>14.71</td>
<td>304.66</td>
<td>13.28</td>
<td>298.63</td>
<td>n/a</td>
<td>52.70</td>
<td>54.35</td>
</tr>
<tr>
<td>N=34</td>
<td>S.D. 3.6</td>
<td>0.53</td>
<td>35.18</td>
<td>3.73</td>
<td>25.42</td>
<td>3.67</td>
<td>29.91</td>
<td>n/a</td>
<td>8.48</td>
<td>14.06</td>
</tr>
<tr>
<td>Institution 7</td>
<td>25.4</td>
<td>3.17</td>
<td>78.44</td>
<td>14.81</td>
<td>315.11</td>
<td>14.82</td>
<td>306.30</td>
<td>4.00</td>
<td>68.04</td>
<td>58.57</td>
</tr>
<tr>
<td>N=27</td>
<td>S.D. 7.2</td>
<td>0.38</td>
<td>18.98</td>
<td>4.78</td>
<td>22.50</td>
<td>4.56</td>
<td>29.97</td>
<td>0.62</td>
<td>10.28</td>
<td>11.69</td>
</tr>
<tr>
<td>All Participants</td>
<td>Mean 24.0</td>
<td>3.17</td>
<td>74.57</td>
<td>14.59</td>
<td>303.59</td>
<td>14.80</td>
<td>295.66</td>
<td>3.40</td>
<td>55.56</td>
<td>58.51</td>
</tr>
<tr>
<td>S.D. 5.1</td>
<td>0.39</td>
<td>32.38</td>
<td>4.06</td>
<td>27.28</td>
<td>4.25</td>
<td>28.96</td>
<td>0.78</td>
<td>12.85</td>
<td>13.21</td>
<td></td>
</tr>
</tbody>
</table>

n/a = not available
The baseline CCTST score for the sample was 14.6 (±4.1). Overall, mean scores for participants at each institution were comparable, ranging from 13.2 to 15.1 with similar variability. Scores for the second administration of the CCTST were similar to those obtained at baseline. The CCTDI baseline scores for all subjects ranged from 241.0 to 367.0, with an overall mean score of 303.6 (±27.3). Mean CCTDI scores for subjects at participating institutions ranged from 294.4 to 315.1. Second administration of the CCTDI resulted in a slight decrease in scores across all institutions.

Faculty rating scores were obtained from all institutions, with the exception of Institution 6. The mean faculty rating scores for students from the six institutions ranged from a low of 2.97 for Institution 5 to a high of 4.07 for Institution 2 (out of a possible mean score of 5). Overall, a mean score of 3.40 (±0.78) was obtained for all students in the sample. Clinical reasoning scores, computed as the percent of items students answered correctly, varied widely. Institution 4 had the lowest mean score for their students in contrast to students at Institutions 2 and 7. The remaining institutions had scores that ranged from 52.70 to 55.50. Overall, students’ mean score across all institutions was 55.56 (±12.85).

Acquired knowledge scores, computed as the percent of items answered correctly, varied by institution as well. The mean score for the total sample was 58.51 (±13.21) with students from Institution 2 scoring highest with a mean score of 70.21 (±15.91). Mean scores and standard deviations for the remaining institutions were relatively similar.

Correlations among predictor and criterion variables varied in both strength and direction (Table 2). The majority of correlations between predictor variables were weak and nonsignificant; however, the relationship between number of college hours completed and age was statistically significant (r = .262), as was the correlation between total CCTDI and CCTST scores (r = .408). It is particularly interesting that neither CCTST nor CCTDI scores were correlated with entering GPA or entering college hours, suggesting that these constructs are different from acquired ability. In additional, the relationship between the initial and final administrations of the CCTST and CCTDI were fairly strong at r = .633 and r = .698, respectively. The strength and direction of the relationships of the final scores of CCTST and CCTDI with criterion measures were very similar to those observed for initial CCTST and CCTDI scores. Not surprisingly, the relationship between clinical reasoning and the other criterion measures of acquired knowledge and faculty rating were moderate and statistically significant (r = .481 and r = .368, respectively).

Descriptive data suggested several preliminary analyses were appropriate to examine the degree to which relationships among measures might attenuate or otherwise affect examination of the primary hypotheses. A primary assumption underlying critical thinking skills and disposition is that these constructs are largely unaffected by traditional curricular courses, but do tend to increase as a function of general education and/or a specific logic course. Therefore, separate regression analyses were used to examine the contribution of scores from the second administration of the CCTST, when entered last in the model for each outcome measure while controlling for institution and initial CCTST scores. Similarly, the second administration of the CCTDI was modeled in the same manner. These results showed that the second administration of the critical thinking measures had a very small effect on the cri-

<table>
<thead>
<tr>
<th>Table 2. Correlations among predictor and criterion variables</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Predictor Variables</strong></td>
</tr>
<tr>
<td>Age</td>
</tr>
<tr>
<td>GPA</td>
</tr>
<tr>
<td>Hours</td>
</tr>
<tr>
<td>CCTST Initial</td>
</tr>
<tr>
<td>CCTST Second</td>
</tr>
<tr>
<td>Knowledge</td>
</tr>
<tr>
<td>Faculty Rating</td>
</tr>
</tbody>
</table>

* Statistically significant p<.05
terion measures with $R^2$ change values that ranged from .001 to .029. Based on these results, the second administration of the CCTST and CCTDI was eliminated from subsequent analyses.

Descriptive data identified institutional differences on the three criterion measures; therefore, a series of regression analyses were performed to determine the degree to which the differential effect of institution with predictor variables influenced each of the criterion measures. For each analysis, the predictor variable was entered first into the regression model followed by the dummy-coded institution variable. Cross-product variables between predictor and institution were entered last to test for the equality of slopes in the prediction equations across institutions.

Regression line slopes for the seven institutions were found to be comparable when modeling the predictors’ relationship with clinical reasoning and acquired knowledge. In contrast, assessment of regression line slopes for institutions for faculty rating available from six schools suggested that Institutions 2 and 4 differed significantly from the remaining four institutions. Given the subjective nature of the faculty rating instrument, there was concern that these interactions suggested the possibility of measurement validity problems with these two institutions on this measure. To examine this possibility, an additional analysis was conducted in which the relationship between faculty rating scores and CCTST, and faculty rating scores and CCTDI were examined for each individual institution. While most relationships between CCTST scores and faculty rating scores were moderate and positive for the remaining four institutions, the regression coefficients for Institution 2 and Institution 4 were negative; therefore, results from these institutions were deleted from the subsequent regression analysis in which faculty rating served as the criterion.

To evaluate the predictive validity of CCTST and CCTDI, a series of hierarchical multiple regression analyses were conducted to examine the explained variance contributed by the baseline critical thinking measures (CCTST and CCTDI) beyond that explained by traditional measures of incoming GPA, age, and total college credit hours. In each model, institution was entered in the first step to control for differences in curricular content. Improvement in a model was determined based on the $R^2$ change and significance for each step. A series of three models were run for each of the criterion variables: clinical reasoning, acquired knowledge, and faculty rating of students’ early clinical competence.

Table 3 displays results modeling clinical reasoning as a function of institutional affiliation, traditional predictor variables, and critical thinking variables. Results for this model suggest that institution

### Table 3. Regression model: relationship of predictor variables to initial clinical reasoning

<table>
<thead>
<tr>
<th>Variables in the Model</th>
<th>Model R</th>
<th>$R^2$ Change</th>
<th>F Change</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institution</td>
<td>.602</td>
<td>.362</td>
<td>16.92</td>
<td>.001</td>
</tr>
<tr>
<td>Institution, Age, GPA, Credit Hours</td>
<td>.619</td>
<td>.021</td>
<td>1.99</td>
<td>.116</td>
</tr>
<tr>
<td>Institution, Age, GPA, Credit Hours, CCTST</td>
<td>.657</td>
<td>.049</td>
<td>15.04</td>
<td>.001</td>
</tr>
<tr>
<td>Institution, Age, GPA, Credit Hours, CCTST, CCTDI</td>
<td>.657</td>
<td>.000</td>
<td>.004</td>
<td>.950</td>
</tr>
</tbody>
</table>

### Table 4. Unique variance in initial clinical reasoning by critical thinking measures and acquired knowledge

<table>
<thead>
<tr>
<th>Predictor Variable</th>
<th>Part $r^2$</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institution</td>
<td>.289</td>
<td>.0001</td>
</tr>
<tr>
<td>Age, GPA, Credit Hours</td>
<td>.024</td>
<td>.055</td>
</tr>
<tr>
<td>CCTST</td>
<td>.041</td>
<td>.001</td>
</tr>
<tr>
<td>CCTDI</td>
<td>.000</td>
<td>.950</td>
</tr>
<tr>
<td>Acquired Knowledge</td>
<td>.032</td>
<td>.002</td>
</tr>
</tbody>
</table>

### Table 5. Regression model: relationship of predictor variables to faculty rating of student competence

<table>
<thead>
<tr>
<th>Variables in the Model</th>
<th>Model R</th>
<th>$R^2$ Change</th>
<th>F Change</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institution</td>
<td>.548</td>
<td>.300</td>
<td>14.02</td>
<td>.0001</td>
</tr>
<tr>
<td>Institution, Age, GPA, Credit Hours</td>
<td>.583</td>
<td>.040</td>
<td>1.90</td>
<td>.135</td>
</tr>
<tr>
<td>Institution, Age, GPA, Credit Hours, CCTST</td>
<td>.680</td>
<td>.123</td>
<td>21.46</td>
<td>.0001</td>
</tr>
<tr>
<td>Institution, Age, GPA, Credit Hours, CCTST, CCTDI</td>
<td>.689</td>
<td>.012</td>
<td>2.09</td>
<td>.152</td>
</tr>
</tbody>
</table>
affiliation explained the largest proportion of variance (R^2 change = .36) in clinical reasoning, whereas the traditional predictors of age, GPA, and number of college hours completed were not statistically significant predictors and collectively contributed only 2 percent of variance. The contribution of baseline CCTST scores significantly improved the model and explained an additional 4.9 percent of variance. CCTDI scores did not contribute to the variance explained in clinical reasoning (R^2 change = .00).

A second model was examined to determine the degree to which acquired knowledge over the semester explained additional variance in clinical reasoning scores beyond that accounted for by variables in the first model. Summary data for this effect and the unique variance (squared part correlation coefficient) explained by the predictors at each step of the full model are displayed in Table 4. Including knowledge acquired over the semester in the model resulted in a statistically significant improvement in unique explained variance in clinical reasoning (R^2 change = .032), although the amount of improvement is relatively small.

Linear regression modeling the relationship of CCTST and CCTDI to faculty ratings of students’ clinical competence is displayed in Table 5. As with clinical reasoning, these results demonstrate the significant effect of institution on faculty rating of students (R^2 = .300). A small and nonsignificant increase in explained variance was noted for traditional variables (R^2 change = .040), whereas CCTST scores were statistically significant and explained 12.3 percent of variance in the outcome measure. CCTDI did not contribute a significant proportion of variance in faculty rating (R^2 change = .012). Overall, the proportion of variance accounted for in faculty rating of students’ competence for this model was 47.4 percent.

As with the previous outcome variable, a second model was examined that included acquired knowledge over the semester. Summary data for the unique variance (Part r^2) accounted for by critical thinking variables and acquired knowledge in this model are displayed in Table 6. Adding acquired preclinical knowledge to the model did not significantly increase explained variance in faculty rating. The unique variance explained by the baseline CCTST was moderate (Part r^2 = .072, p = .001). Institutional affiliation clearly predicted the greatest amount of unique variance (Part r^2 = .258) to total variance explained by the full model.

A fifth series of models examined the relationship of CCTST and CCTDI to students’ acquired preclinical knowledge. The summary data for this model are displayed in Table 7. Results for this model demonstrate a statistically significant effect of institution on acquired knowledge of students (R^2 = .112). When the set of traditional predictors (GPA, age, and total credit hours) was added to the model, there was a small but significant increase in proportion of explained variance in acquired knowledge (R^2 change = .041). The addition of baseline CCTST scores resulted in a statistically significant improvement in explaining variance in the model (R^2 change = .115). Adding the scores from the CCTDI did not result in model improvement. Overall, the proportion of variance accounted for in acquired preclinical knowledge for this model was 27.1 percent, of which CCTST scores contributed the most variance.

The unique proportion of variance (Part r^2) explained in acquired knowledge by the traditional predictor variables and respective critical thinking measures are displayed in Table 8. Of the 11.8 percent of total variance in acquired knowledge accounted for by the critical thinking measures collectively,
baseline CCTST was determined to comprise the greatest proportion (Part $r^2 = .084$). This suggests that these measures shared approximately 3.0 percent of variance in the outcome measure. Of particular interest was the unique variance explained by institutional affiliation (Part $r^2 = .072$) in the final model.

### Discussion

**Critical Thinking Measures as Predictors**

The primary purpose of this investigation was to examine the predictive validity of two critical thinking measures on the clinical reasoning of first-year dental hygiene students. Three criterion measures were used to assess students’ initial clinical performance: faculty rating of student competence; clinical reasoning using a case-based format; and acquired knowledge over the semester. The results of this investigation suggest that critical thinking skill, as measured by the CCTST, was a more consistent predictor of student performance on all criterion measures than traditional predictors (age, GPA, and number of college hours at entry into dental hygiene). Not surprisingly, institutional affiliation of the students was a primary predictor of student performance on all measures. It is probable that differences among institutions with respect to course content, preclinical faculty, and student characteristics were collectively responsible for the large proportion of variance explained in outcome measures. This variable was accounted for in each model to examine the degree to which variations in institutions impacted outcomes.

CCTST scores were the most predictive of acquired knowledge, as opposed to clinical reasoning and clinical performance, and explained an additional 11.5 percent of the variance above that explained by institutional affiliation and traditional admissions measures. Of interest, only 4.1 percent of variance in acquired knowledge was explained collectively by traditional entry measures, GPA, student’s age, and number of credit hours at entry into program. For the remaining outcome measures (clinical reasoning and faculty rating), CCTST contributed 4.1 percent and 7.2 percent to the explained variance, respectively. These results were somewhat surprising since a primary assumption underlying the hypothesis was that critical thinking skills were highly aligned with clinical reasoning and clinical performance. The clinical reasoning measure was based on clinical cases from which students had to extrapolate information to answer multiple-choice questions. It is possible that since students had little experience in case-based application and were more familiar with objective, stand-alone questions, those students with better critical thinking skills were better able to answer knowledge-based multiple-choice items. It is also possible that, at this early stage of clinical experience, they are more likely to be able to correctly identify objective information and less able to apply the information to simulated clinical cases, irrespective of critical thinking ability.

Previous studies that examined the relationship between context-general critical thinking and context-specific clinical reasoning have yielded equivocal findings. Although some studies failed to find a significant relationship between critical thinking and clinical reasoning, other studies agree with the current investigation results. A primary criticism of the studies that failed to support a relationship between critical thinking and clinical reasoning is grounded in their respective methodologies. Each of these studies employed a single, but subjective measure of clinical reasoning. In contrast, those studies showing a statistically significant relationship utilized singular outcome measures, but measures with established validity and reliability. It is interesting to note that magnitude of the relationships between critical thinking and clinical reasoning found by Brooks and Shepard and Sorensen-Bowles were .21 and .25, respectively. The current investigation showed similar zero-order (bivariate) correlations between CCTST and outcome measures.

The unique variance attributable to the CCTST on each outcome measure was relatively small; however, it is interesting that it exceeded that attributable to traditional predictors of age, GPA at entry, and number of college hours taken. The proportion of explained variance in acquired knowledge was

---

<table>
<thead>
<tr>
<th>Table 8. Unique variance in acquired knowledge by critical thinking measures</th>
<th>Predictor Variable</th>
<th>Part $r^2$</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institution</td>
<td>.075</td>
<td>.008</td>
<td></td>
</tr>
<tr>
<td>Age, GPA, Credit Hours</td>
<td>.030</td>
<td>.072</td>
<td></td>
</tr>
<tr>
<td>CCTST</td>
<td>.084</td>
<td>.001</td>
<td></td>
</tr>
<tr>
<td>CCTDI</td>
<td>.003</td>
<td>.437</td>
<td></td>
</tr>
</tbody>
</table>
greatest of the three. However, the purpose of using three outcome measures was to enhance generalizability of conclusions as suggested by Cook and Campbell. From a practical perspective, one can argue that the overall contribution of CCTST to predicting initial clinical ability, as measured by the three outcome measures, was not overwhelmingly impressive. In spite of this, critical thinking skills did show utility in predicting outcomes that exceeds that for traditional measures. The cost-benefit of using the CCTST as admission criteria was not considered in this investigation, nor was the predictive validity of CCTST for performance on national and regional board exams. Clearly, there is a need for more studies that will clarify the scope of relationships between critical thinking skills and other meaningful outcomes.

In contrast, critical thinking disposition as measured by the CCTDI showed no utility in predicting clinical reasoning, faculty rating of student competence, or acquired knowledge. A strength of the current investigation was the use of both measures of critical thinking, thus allowing for the unique and shared contribution of these measures on the multiple outcomes. One could hypothesize that if clinical reasoning was largely a function of critical thinking and that critical thinking was composed of both skills (cognitive domain) and disposition (affection domain), then the CCTDI would have predictive validity above that of the CCTST. Such was not the case with our investigation.

Change in Critical Thinking and Critical Disposition

A second administration of the CCTST and CCTDI was performed to examine differential change in critical thinking abilities as a function of institution. It is generally agreed that a significant change in critical thinking skills and/or disposition is unlikely in a short period of time unless students have specific training or experience in applied logic and reasoning. Cross-sectional and longitudinal studies have shown students tend to have a small, insignificant increase in critical thinking skills as they progress in their initial educational experiences. Improvement in scores tends to increase to significant levels over several years of study or as a function of different levels of academic completion. The preliminary analyses from this study support the contention that little change in critical thinking occurs during the first semester. Although there was a very slight influence of change in CCTST scores on the predictability of clinical reasoning scores, it was deemed to be unimportant relative to the overall hypotheses of interest in this study.

From a diagnostic perspective, the lack of significant change in CCTST scores from baseline to the second administration also suggests that clinical thinking isn’t being directly taught as part of the early clinical curriculum. If the desired outcome of allied dental education is to produce clinicians with good critical thinking and clinical reasoning skills, then it is logical that learning strategies aimed directly at enhancing these skills should be incorporated into preclinical and early clinical education. Halpern proposes a four-part strategy based on cognitive psychology theory that involves: assisting learners in determining when critical thinking skills are needed; teaching context-specific macroabilities of argument analysis, hypothesis testing, and problem-solving skills; enhancing transferable thinking skills though the elaboration of concepts in real-life situations; and integrating metacognitive monitoring strategies into the application of critical-thinking learning situations. Halpern proposes that this multifaceted approach will improve the overall critical thinking of learners and improve transferability across domains. Whether this approach applies to enhanced clinical reasoning still needs to be evaluated.

Limitations and Implications for Allied Dental Education

During the preliminary phase of the study, the expert panel was charged with developing a valid faculty rating scale, among other measures, that was appropriate for assessing initial student competence with respect to the dental hygiene process of care. Content-related validity for the scale was established by panel consensus using educational objectives from baccalaureate dental hygiene programs. However, preliminary data analyses suggested a potential interaction effect between institution and predictor variables on the faculty rating scale. Subsequent regression analyses demonstrated an inequality of slopes in prediction equations for Institutions 2 and 4 for this measure, resulting in a loss of subjects for this one analysis. The loss of participants from Institutions 2 and 4, together with the lack of response on faculty rating data for Institution 6, reduced the sample size for the regression model predicting faculty rating to 107. While this effectively limits both power and generalizability to some degree, the ratio...
of subjects to variables in the model (approximately 15:1) gives some support to the stability of the results. However, results obtained from only four programs may not generalize to the total population of twenty-two baccalaureate programs in dental hygiene.

More critically, the problems encountered with the faculty rating scale, in spite of calibration efforts, clearly point to inherent deficiencies with the subjective rating of initial student clinical competence. Although subjective assessment of clinical performance is commonly used and considered a valid approach in dental education, these results convey potential limitations with this assumption across institutions. Messick, in addressing the validity of performance assessments, suggests that domain coverage and generalizability need careful attention. Essentially, assessment of student competence should be based on observation of multiple performances. During phase one of the study, it was determined that each institution had multiple task-oriented assessments throughout its preclinical and early clinical curricula that would serve to provide observation of multiple performances. Each of the site coordinators expressed confidence that the multiple performance evaluations would assist faculty in completing the faculty rating scale of overall student competence. However, since individual task-oriented assessments were not standardized between programs, it is possible that the task-oriented assessments varied in breadth and depth with regard to domain coverage, thus inadvertently influencing faculty’s rating.

Further research is needed, using both quantitative and qualitative methods, to clarify the degree to which critical thinking is related to clinical reasoning, as well as to determine how best to facilitate clinical reasoning skills of students for all educational program types. Quantitative research aimed at understanding the relationship between context-general critical thinking skills and other predictors of student success would be valuable. Although the current investigation examined common admission criteria, it did not include all possible admissions criteria. Standardized college entry exams, such as the ACT and SAT, are sometimes used as selection criteria in health professions programs. Scott reported that only 19 percent of allied health programs used SAT results as part of their entry criteria, but did not address the use of ACT scores. Future studies are needed in which the unique variance in student performance measures is examined for the CCTST and CCTDI, above that explained by standardized test scores and other common admissions predictors. This was not examined in the current study because most of the programs did not require recent ACT or SAT scores for program admission.

It is anticipated that the characteristics of students seeking admission into dental hygiene will change as career opportunities either increase or decrease. Tracking the cognitive and affective critical thinking attributes of successive classes might also assist educators in selecting and/or meeting the needs of student populations as they change.

In dental hygiene and dental education, it is still unknown how students’ critical thinking ability and disposition impact learning, decision-making, and clinical performance. The CCTST and CCTDI assess general critical thinking about everyday life rather than context-specific reasoning. In general thinking, individuals do not always consider all possible courses of action before making a decision. Rather, they tend to make decisions with which they are comfortable or that replicate previous experience. In the delivery of health care, the desired critical thinking process is one that involves conscious deliberation about what to do and how best to do it to achieve good outcomes.

In nursing and occupational therapy, qualitative research has been used to examine decision-making and clinical judgment skills of students and inexperienced and experienced clinicians. In general, these studies have clarified the mental processes used to arrive at clinical decisions and suggest that processes become more refined and rapid with experience. Similar studies in dental hygiene and dental education would help elucidate clinical reasoning processes and allow for examination of these processes as a function of general critical thinking abilities. This in turn could enhance the pedagogical processes in allied dental and dental education.

Conclusions

Results from the current investigation suggest that critical thinking skills, as measured by the CCTST, explain a statistically significant proportion of variance in initial clinical performance as measured by the three outcome measures. Additionally, the degree to which CCTST explains variance in the outcomes exceeded that predicted by entering GPA,
number of college hours, and students’ age. The CCTST was especially effective as a predictor of acquired knowledge. Critical thinking disposition (CCTDI) did not play a comparable role in predicting initial student outcomes. With the current emphasis on educating students who are capable of good clinical reasoning in allied dental and dental education, coupled with the early evidence that faculty do little to teach clinical reasoning, continued research in this area is warranted. This may have implications for student selection and retention, faculty development, and pedagogical practices. As dental educators improve their understanding of how students develop clinical reasoning skills, the learning environment can be modified to foster growth in these areas. Pedagogical practices that facilitate the acquisition of knowledge as well as the development of critical thinking can then be implemented and evaluated.

Acknowledgments
We thank the ADHA Institute for Oral Health and ADEA/Young Dental Manufacturing Company Dental Hygiene Development Grant for funding of this study. We also thank Nona Tollefson, Ph.D., John Poggi, Ph.D., Janet Marquis, Ph.D., Pamela Duncan, P.T., Ph.D., Daniel Tira, Ph.D., and William Mayberry, Ph.D., for their advice and support on the development of this project.

REFERENCES