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ORIGINAL RESEARCH

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CRITICAL THINKING, CLINICAL REASONING SKILLS AND COGNITIVE ABILITIES OF DENTAL STUDENTS

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ABSTRACT

Background: Critical thinking (CT) and clinical reasoning (CR), along with adequate clinical knowledge, are crucial components of thinking in clinical practice. This study aimed to assess, compare and analyze the relationship between CT skills, CR skills, and cognitive abilities in undergraduate (UDS) and clinical dental students (CDS).

Methods: This natural experimental study was conducted using the quantitative descriptive-analytic methods with a cross-sectional design. Thirty UDS and sixty-one CDS were selected purposively. Demographic and academic data were obtained through questionnaires. The Critical Thinking Tool (CriTT) was used to measure CT skills, and CR skills were measured by the Diagnostic Thinking Inventory (DTI). Knowledge acquisition was measured through the Cognitive Ability Test (CAT), which is a set of multiple-choice questions specifically developed and validated for this study. The statistical differences between them were analyzed by one-way ANOVA, and their relationship was tested by correlation matrix analyses.

Results: There were no differences in CriTT measurements between groups. The overall DTI score and subscale 2 (Structure of memory) showed significant differences between groups, as did the overall CAT score and all clinical science subscales. Correlation matrix analyses revealed CR skills were related to CT skills, while the cognitive abilities or knowledge acquisition were related to CR skills.

Conclusion: Results showed the CR skills and cognitive abilities of clinical dental students are superior to undergraduate dental students. Generally, the results indicated the more skilled students are in critical thinking, the better are their clinical reasoning skills. Better cognitive abilities tended to improve clinical reasoning skills.

Keywords: Dental student, critical thinking skills, Critical Thinking Tool, clinical reasoning skills, Diagnostic Thinking Inventory, cognitive abilities

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PRACTICE POINTS

- While many studies focus on critical thinking and clinical reasoning, there are few studies in dentistry, especially among dental students in Indonesia.
- Critical thinking is prioritized in determining the competence of new dentists in Indonesia, while clinical reasoning, which is the main skill of many health professionals, has not been typically applied and measured during dental education and clinical training.
- Critical thinking, clinical reasoning skills and cognitive abilities contribute to clinical thinking during problem-solving and decision-making. Dentists are expected to have these skills and abilities in order to be competent professionals.

INTRODUCTION

Challenges in Providing Dental and Oral Health Services

The pattern of oral health care services is influenced by various challenges, including changes in risk and disease patterns, socio-economic and political conditions, demographic and epidemiological transitions, and medical advances. Oral health care services have become increasingly complex, which initially focused on teeth and their supporting tissues, but now have to consider systemic conditions, their management and oral manifestations.[1,2] These conditions have an impact on the way dentists are trained, because it is related to the appropriateness, quality and efficiency of the treatment and preventive delivery services available to the population.[3] This has substantially changed the goals of dental education, with greater emphasis on the importance of clinical reasoning for competent dentists.[4] Robust and comprehensive clinical reasoning skills enable dentists to identify, compile and process information according to clinical presentations, understand problems, make accurate clinical decisions and be open-minded about available treatment options, plan and perform interventions, and evaluate the results of therapeutic decisions.[5]

The Concept of Clinical Thinking in Dentistry

Clinical thinking is necessary for health professionals to deal with complex clinical problems, which involve critical thinking, clinical reasoning, problem solving, clinical judgment and decision-making. Clinical thinking represents the clinician's cognitive abilities while working in clinical practice.[6,7] Critical thinking is described as an intellectual, skilled, and responsible way of thinking, which facilitates the transition into clinical environment.[8,9] Clinical reasoning is a professional act of thinking in clinical situations.[10,11] The diagnostic task of health professional is relevant to their 'problem space'.[12] A clinician's problem space is a personal perspective when viewing, interpreting, and framing a clinical problem, which requires individual and professional knowledge, clinical experience, and values.[13] The medical diagnostic task generally aimed at establishing a diagnosis, contrary to the dental diagnostic task which mostly pointed at the end of health services. Contemporary dental care can be either curative or rehabilitative that focuses on aesthetics, which is related to classic dental service pattern which is dominated by procedural practices.[14] Dental decision-making is typically related to the preventive approach rather than problem-solving, and dentists usually choose between alternative treatments, such as tooth filling versus extraction.[15] Consideration of the differential diagnosis is less important unless it involves oral soft tissue abnormalities. Oral health care approaches generally focus on health rather than disease.[16]

The Current Situation of Dental Education

To date, dental education typically encompasses the didactic stage followed by periods of clinical training in dental clinics or hospitals settings.[3] Most dental schools emphasize a procedure-driven curriculum, accounting for about 50%, while the rest are basic, biomedical, behavioral knowledge, and other areas

necessary for a dentist to become a competent professional. This combination of basic/biomedical knowledge is generally acquired during the didactic stage, while the later procedural and diagnostic clinical knowledge, skills, and attitudes occupy the clinical training stage.[17,18] Basic and biomedical sciences play an important role in the development of clinical knowledge, specifically during clinical problem-solving and decision-making processes. Both tasks require critical thinking skills and clinical reasoning.[6,7,10,19]

Observations on Critical Thinking, Clinical Reasoning Skills, and Cognitive Abilities

Observations on critical thinking skills are generally quantitative via standardized instruments,[20–25] such as The California Critical Thinking Skills Test (CCTST),[25] The Health Sciences Reasoning Test (HSRT)[21,22] and Critical Thinking Tool (CriTT).[23] Clinical reasoning skills are mostly related to diagnostic thinking and are commonly observed quantitatively by class or clinical assessment methods.[26–29] However, some standardized instruments are known to be able to assess reasoning skills, for example, Diagnostic Thinking Processes (DTP) and Diagnostic Thinking Inventory (DTI).[27,30–32] Cognitive ability refers to mental processes for problem-solving, through discrimination, analyzing, predicting, reasoning, information seeking, and transforming knowledge.[33]

Cognitive ability is the problem-solving skill with success determined by knowledge. Its measurement is similar to reasoning, made through various classroom assessments. Generally, the observation of these skills or abilities is associated with teaching methods, curriculum changes, or learning instructions.[26,34] To date, there is a lack of published studies on the relationship between critical thinking, clinical reasoning skills, and cognitive abilities in dental students.

The Aims of the Study

This study aimed to assess, compare and analyze the relationship between critical thinking, clinical reasoning skills, and cognitive abilities in undergraduate (UDS) and clinical dental students (CDS).

METHODS

Research Design

This research was a correlational study, which was conducted using naturalistic observation. Data were collected through a quantitative-based cross-sectional design and statistically processed by descriptive-analytic methods.

Setting

The study was conducted on dental students, Faculty of Dentistry, Universitas Gadjah Mada, Yogyakarta, Indonesia. The natural experimental study refers to observational research without intervention but is influenced by conditions beyond the control of the researcher. The natural condition in this study is the learning process engaged in by each respondent. Both groups underwent didactic learning processes with a similar curriculum.

Subject and Sampling

The target population was dental students. The study population was undergraduate (UDS) and clinical dental students (CDS). Purposive sampling was used to identify participants. The total number of participants was 91 students, divided into two groups consisted 30 UDS and 61 CDS. All participants met the inclusion and exclusion criteria. General inclusion criteria were: 1) taking a similar curriculum, 2) being physically and mentally healthy, 3) being willing to provide the necessary information, and 4) being able to complete the study. Specific inclusion criteria for UDS were: those who have completed didactic lessons, but have not graduated; and have completed clinical rotations for the clinical student. The informed consent form was signed after the participants understood and agreed to participate in the study. Participation was voluntary and the students could withdraw at any time.

Data Collection Tools

Demographic and academic data were obtained through questionnaires, and comprised of age, gender, and the level of academic achievement. The psychometric assessment, CriTT[23] was used to measure critical thinking skills, and clinical reasoning

skills were measured by DTI.[35] Cognitive ability data was obtained through multiple choice questions (MCQ) with four options and one correct answer.

In constructing CriTT, Stupple[23] generated items using the transcripts from interviews and focus groups, later analyzing them using factor analytic methods to decide which items to retain in the instrument. These procedures resulted in a final instrument consisting of 27 items divided into three subscales. Each item contains a stem followed by a ten-point similar to the Visual Analog Scale. Seventeen items loaded onto subscale 1: confidence in critical thinking, which related to self-efficacy, confidence, and behavior. Six items grouped on to subscale 2: valuing critical thinking, which is related to the perceived utility of critical thinking. Four items were gathered on subscale 3: misconceptions, which related to misconception in higher education, critical thinking, and conceptual knowledge. Their internal consistency demonstrated high reliability for subscales 1 and 2, while the subscale 3 demonstrated moderate reliability.

The items of DTI were developed directly from the findings of Bordage, Grant, and Marsden's research on the medical diagnosis and clinical reasoning.[35] The instrument consists of 56 items divided into three subscales. Each item contains a stem followed by a 6-point, semantic-differential type scale. Thirty-one items grouped on to subscale 1: flexibility in thinking, which refers to the use of a variety of thinking processes during the diagnostic process. Twenty-five items loaded onto subscale 2: Structure in memory, which refers to the availability of knowledge stored in memory during the diagnostic process. All items were analyzed and the internal consistency demonstrated high reliability for overall DTI, and moderate reliability for each subscale.

Cognitive test development takes place in several stages, starting with the determination of the context and content of question items, validation, and finalization of the test set. The context and content of the cognitive test have considered the scope of dental knowledge, competency, and expertise in dentistry.[36] These items were grouped into five subscales: 1. basic-biomedical (15-Q) 2. procedural-instrumental (15-Q) 3. procedural-invasive (15-Q) 4. Diagnostic knowledge (25-Q), and 5. complex clinical cases (30-Q).

Data Analysis

All data are presented descriptively through Microsoft Excel. The mean differences of CRiTT, DTI, CAT, and their subscales measurement in both groups were tested by one-way ANOVA followed by Tukey post-hoc analyses. The relationship between critical thinking, clinical reasoning skills, and cognitive abilities was confirmed through correlation matrix analyses. The statistical test results are declared significant if $p<0.01$. All statistical analyses used Jamovi 1,6,8®, an open-source statistical program (https://www.jamovi.org/ download.html) and are presented in tabular and graphs.

Study Procedures

This research can be divided into the initial and main studies.

a. The initial study included the translation and validation of both CriTT and DTI instruments, as well as the development and validation of cognitive ability tests (CAT). After obtaining written permission from the instrument developers, the standardized CriTT and DTI were translated into Bahasa Indonesia by a licensed translator from the Faculty of Cultural Sciences UGM. The validation was done through peer review, to adjust the translation results to the appropriate medical term. The DTI instrument was later modified by adding clinical vignettes as a participant's guide in responding to item statements. Their internal consistency was tested since no study has reported their use in dental students. Both of them showed high reliability with Cronbach's alpha coefficient between 0.75 - 0.95.

   The cognitive levels of CAT are categorized by a simplified Bloom's taxonomy,[37] covering 13% recall or memory, 34% application, and 53% analysis, which were spread evenly between subscales. The test item was arranged as a classic stem-lead in-option. For validation, each item is written in a detailed template, which includes domain, basic competence and skills, cognitive level, stem-lead in-option, best answer and clarification, references, and peer-review evaluation. Peer review is done with colleagues rated the items on plausibility, clarity, wording,

relevance, and level of difficulty.[38] The level of difficulty rated by colleagues was balanced between simple (48%) and complex (52%). The final CAT consists of a hundred MCQ items.

b. The main study encompassed demographic/ academic data collection, critical thinking, clinical reasoning skills, and cognitive abilities measurements. All of them are packaged into one and filled out in a single day.

c. All data obtained were arranged tabularly through Microsoft Excel, and later transferred to Jamovi Statistical Software, and statistically processed.

Figure 1 depicts a flowchart to describe the methods better.

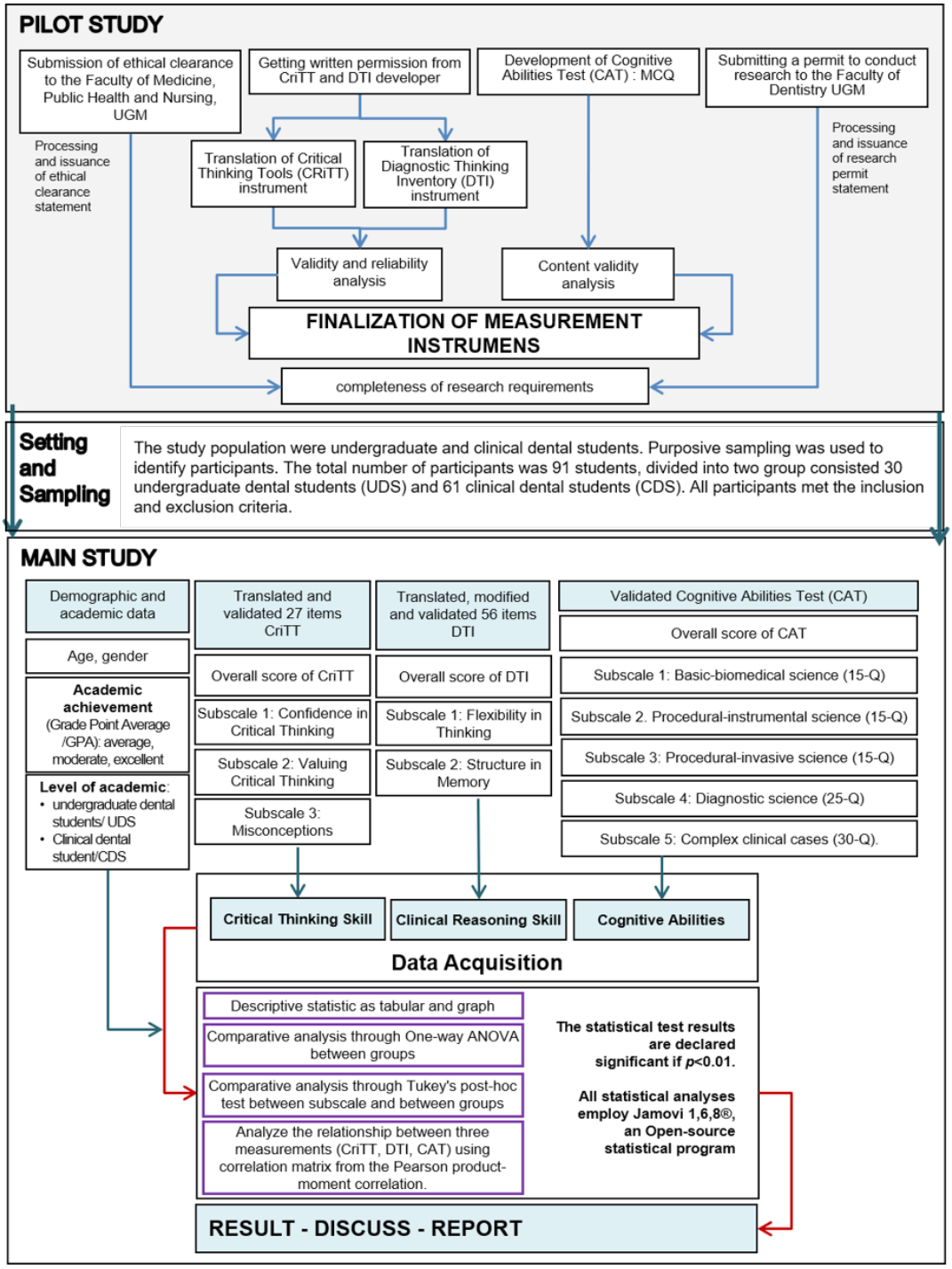

Figure 1. The Flowchart of Study Procedure, which Differentiated to Initial and Main Study

Ethical Approval

This study was approved by the Medical and Health Research Ethics Committee, Faculty of Medicine, Public Health and Nursing, Universitas Gadjah Mada (No: KE/FK/1183/EC/2019), and the study protocol has complied with the Declaration of Helsinki concerning the research ethical principles involving human subjects. Research was conducted after obtaining permission from the Faculty of Dentistry, Universitas Gadjah Mada, Yogyakarta Indonesia (No.11709/UN1/FKG.1/Set.KGI/ LT/2019). The research was conducted at the end of 2019.

RESULTS AND DISCUSSION

Based on demographic data, most of the participants were female with an age range between 20-27 years, and most of the participants are less than 23 years (76.67%) in the UDS and 23 years (59.02%) in the CDS group. The gender proportion is predominately females. Female domination or feminization needs to be a concern, given the reports that it has an impact on the resources, characteristics, and professional practice of the ideal dentist.[39] The practice of female dentists is generally based on a philosophy of promotion and prevention, with a more conservative approach to treatment.[40] However, the effect of gender on critical thinking skills varied, and mostly showed no significant impact.[41] The level of academic achievement is expressed as Grade Point Average (GPA), and divided into average (GPA<3), moderate (3<GPA<3.5), and excellent (GPA>3.5). Most of the participants were at moderate academic achievement (50% for UDS and 54.1% for CDS), while more CDS participants were at excellent academic achievement compared to UDS. Some studies reported that academic achievement is closely related to critical thinking skills and argumentation skills.[21,42] But in this study, their critical thinking and clinical reasoning skills did not show differences between academic achievement (based on GPA categorization) except for cognitive abilities. This result is in line with the study results by van der Zanden et al.,[43] that found academic achievements were particularly related to student characteristics, whereas critical thinking skills were more related to the learning environment. Furthermore, Krathwol[37] stated that academic achievement reflects cognitive abilities. This finding is in accordance with the results of this study which showed a significant difference in cognitive abilities between academic achievement.

The Results of Measurement and Discussion of Critical Thinking Skills

Table 1 shows the distribution of the mean, the standard deviation of overall CriTT and their subscales scoring each group, and the result of one-way ANOVA statistical tests between-group. The results showed no differences in overall CriTT and their subscales between UDS and CDS groups. However, CDS more valued critical thinking skills than UDS participants, which is presented by a negative t-test value that indicates the lower mean score of CriTT in the UDS group.

Table 1. The Results of One-Way ANOVA between Overall CriTT and Their Subscales

	n	UDS (n=30) Mean ± SD	CDS (n=61) Mean ± SD	Mean difference	t-test value	df	*p-value*
CriTT	27	204.7 ± 19.87	205.8±24.57	-1.14	-0.220	89	0.826
CCT	17	122.9 ± 15.22	123.6±18.47	-0.373	-0.0961	89	0.924
VCT	6	51.3 ± 5.49	82.6±8.45	-0.306	-0.271	89	0.787
Mc	4	30.1 ± 4.89	30.6 ± 4.57	-0.457	-0.438	89	0,662

Note. * $p < .05$, ** $p < .01$, *** $p < .00$; UDS/CDS, Undergraduate/Clinical dental student; SD, standard deviation

This study result is consistent with the results of the study conducted by Pardamean[21] that used standardized HSRT to measure the critical thinking skills of different levels of dental students, before and after the PBL session. Research conducted by Hanlon et al.[22] using standardized HSRT showed that novice critical thinking skills are different from experts, as shown by an experienced dentists who achieved

significantly better overall scores compared to first-year dental students. The CriTT used in this study is a newly developed instrument, which is reported to be reliability for measuring critical thinking skills,[23,44] but no study has reported its use to compare critical thinking skills between any groups. This instrument is intended to psychometrically measure critical thinking beliefs and attitudes, predict academic performance, and identify the need for additional support about critical thinking.

Critical thinking is a process of active and skilled intellectual discipline, in order to be able to conceptualize, apply, analyze, synthesize, and evaluate information generated through observation, experience, reflection, reasoning, and communication.[8] Critical thinking skills are built from an early age and honed through education and experience. Critical thinking skills are related to success at every stage of education and students with higher critical thinking skills tend to complete education faster with higher academic achievement.[8,23]

The Result of Measurement and Discussion of Clinical Reasoning Skills

The development of the DTI is intended to measures diagnostic thinking /clinical reasoning skills. Table 2 presents the distribution of the mean, the standard deviation of overall DTI, and their subscales scoring each group and the result of one-way ANOVA statistical tests between-group. The result of one-way ANOVA statistical tests showed significant differences ($p<0.05$) between the UDS and CDS groups in DTI overall score and 'subscale 2: Structure of memory'.

Table 2. The Results of One-Way ANOVA between Overall DTI and Their Subscales Score

	n	UDS (n=30) Mean ± SD	CDS (n=61) Mean ± SD	Mean difference	t-test value	df	*p-value*
DTI	41	156.8 ± 15.61	164.7±15.50	-7.89*	-2.28	89	0.025
Flexibility in thinking	21	77.0 ± 10.28	82.0±10.30	-2.87	-1.54	89	0.128
Structure of memory	20	79.8 ± 8.22	82.6±8.45	-5.02*	-2.19	89	0.031

Note. * $p < .05$, ** $p < .01$, *** $p < .001$; UDS/CDS, Undergraduate/Clinical dental student; SD, standard deviation

Since Bordage et al.[35] define flexibility in thinking as the use of multiple thought processes during the clinical situation, it can be assumed that these skills develop when dealing with clinical problem-solving and decision-making. Clinical exposure and experience are the hallmarks of a clinician's expertise, and problem-solving and decision-making skills in clinical situations influence the DTI assessment, particularly 'the subscale1: Flexibility in thinking'. Boshuizen and Schmidt[45] place medical students as novices in the stage of medical expertise, so it can be understood that the 'subscale1: Flexibility in thinking' measurement results between the groups did not show any significant difference. However, the flexibility of thinking of CDS was better than UDS participants, which was reflected in the negativity of the t-test value.

This study showed that CDS participants had better clinical reasoning skills as measured by the overall DTI. This finding is likely related to the amount of knowledge acquisition that is organized and structured in memory better than UDS participants, as evidenced by the significant difference in 'subscale 2: structure of memory' measurements between groups. According to the theory of medical expertise, medical students are grouped as novices with two different structures of knowledge, reduced and dispersed.[45] Referring to the study results, it can be assumed that UDS showed reduced knowledge, and dispersed knowledge was shown by CDS. During the didactic stage, the stored knowledge is characterized by reduced knowledge, which then progresses into dispersed knowledge during the clinical stage.[45,46]

There is no report of the use of DTI to measure clinical reasoning skills in different levels of dental students or expertise.[47] A single report on the use of DTI in dental students compared the results of clinical reasoning skills measurement between DTI and Key Feature tests (KFt), a class assessment method.[27] Keshmiri et al.[27] reported that DTI has a similar ability to KFt in measuring the clinical

reasoning skills of senior dental students. The DTI could assess the flexibility in thinking and structure of knowledge in memory independent of content and can evaluate different levels of medical students.[32] Besides being able to capture the development of clinical reasoning skills, the DTI can identify a person's weaknesses and strengths when reasoning.[29]

The Results of Measurement and Discussion of Cognitive Abilities

The Cognitive ability test (CAT) is intended to measure the acquisition of knowledge. Properly constructed MCQ can assess cognitive processing based on Bloom's taxonomies,[48] furthermore MCQ is able to assess higher-order cognitive abilities through a case-based format.[49,50] The CAT has been tested reliably (Cronbach's α=0.722) to measure what it was intended to measure. Based on the UDS group item analysis result, 83% of CAT items had adequate difficulty index, while in the CDS group, there was only 67%. The distribution of the mean, the standard deviation of CAT and their subscales scoring each group, and the result of one-way ANOVA statistical tests between-group are presented in Table 3.

Table 3. The Results of the One-Way ANOVA between Overall CAT and Their Subscales Score

	n	UDS (n=30) Mean ± SD	CDS (n=61) Mean ± SD	Mean difference	t-test value	df	*p-value*
Cognitive Ability Test (CAT)	100	42.30 ± 6.61	51.72±5.89	-9.42***	-6.88*	89	<.001
basic-biomedical science	15	8.07± 2.33	8.48±1.59	-0.409	-0.984	89	0.328
procedural-instrumental science	15	6.80 ± 1.81	7.11±1.92	-0.315	-0.750	89	0.455
invasive-procedural science	15	5.23 ± 1.59	7.10 ± 1.79	-1.87***	-4.85*	89	<.001
diagnostic science	25	9.80 ± 2.57	12.74 ± 2.21	-2.94***	-5.66*	89	<.001
complex clinical science.	30	12.40 ± 3.21	16.23 ± 3.58	-3.83***	-4.95*	89	<.001

Note. * $p < .05$, ** $p < .01$, *** $p < .00$; UDS/CDS, Undergraduate/Clinical dental student; SD, standard deviation

The mean scores of correct answers of the CAT were 42.30 for the UDS and 51.72 for the CDS group. The results of one-way ANOVA tests showed significant difference in the overall CAT score (t = -6.88*; p = <.001) between the UDS and CDS, also for subscale 3 (t = -4.85*; p = <.001), subscale 4 (t = -5.66*; p = <.001) and subscale 5 (t = -4.95*; p = <.001). Subscales 3-4 of CAT reflect dental clinical knowledge, i.e., procedural-invasive, diagnostic, and complex clinical cases respectively. The value of statistical tests in subscales 3, 4, and 5 displayed negativities, indicating cognitive abilities of UDS were lower than in the CDS participants. The analysis results in Table 3 could be more easily understood by presenting them as a spider or radar chart, which is a way to visualize multivariable data (Figure 2).

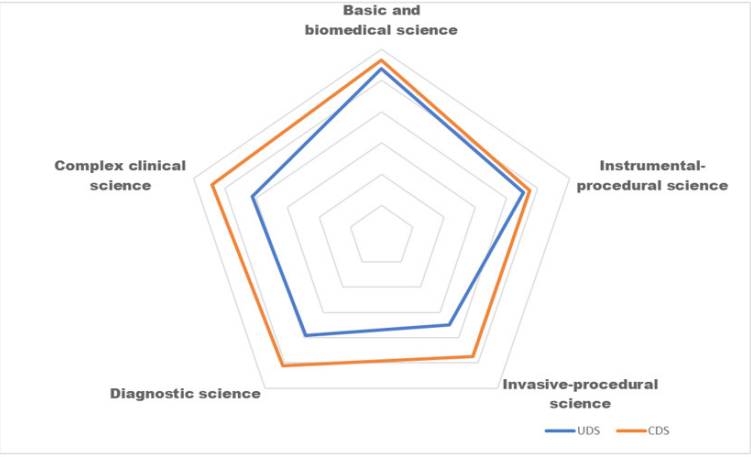

Figure 2. Radar Chart of All Subscales Scores of the CAT. The UDS Scoring Results in Blue Lines and the CDS Scoring Results in Red Lines

The radar chart shows each subscale of CAT in both groups. The measurement data are presented as the length of the axes forming the polygon. Each subscale has its own value, as a result, the polygon chart formed asymmetrically. Visually, the ends of the axes of 'the subscale 1: basic/biomedical' and 'subscale 2: instrumental procedural' of both groups overlap each other, in contrast to the dental clinical knowledge subscales. This graph shows no difference in the measurement of subscales 1 and 2 between-groups. Theories on expertise development assume that biomedical knowledge plays a more prominent role in student's clinical case representation than physician's case representation.[51] Basically, biomedical sciences and basic procedural sciences are the foundation for comprehending clinical knowledge and training skills.[45,46,52] All health professional education providers agreed that basic/biomedical science is important when dealing with clinical situations.

The Relationship between Critical Thinking, Clinical Reasoning Skills, and Cognitive Abilities

The next analysis is intended to see whether there is a relationship between the three measurements: critical thinking skills, clinical reasoning, and cognitive abilities, using correlation matrix analysis (Table 4). This analysis measured the strength of the associations between variables and the direction of the relationship.

Table 4. Correlation Matrix Analysis for the Three Measurements (CriTT, DTI, and CAT) using the Pearson Product-Moment Correlation

Critical thinking skills	1.00		
Clinical reasoning skill	0.539***	1.00	
Cognitive Abilities	0.028	0.246**	1.00
	critical thinking skills	**clinical reasoning skill**	**cognitive abilities**

H_a is positive correlation. * $p < .05$, ** $p < .01$, *** $p < .001$, one-tailed

Pearson correlation evaluates the linear relationship between two continuous variables. The study showed a correlation coefficient (r) =0.539 with $p < .001$ between critical thinking skills and clinical reasoning skills. The correlation coefficient value is between +0.40 to +0.69, which indicates a strong positive relationship. A strong positive correlation means that the graph has an upward slope from left to right: as the x-values increase, the y-values get larger. The results of thse studies mean that as the critical thinking skills measurement increase, the measurement of clinical reasoning skills also increases. The study showed a correlation coefficient (r) =0.246 with $p < .01$ between clinical reasoning skills, and cognitive abilities. The correlation coefficient value is between +0.20 to +0.29 which indicates a weak positive relationship. There was no significant correlation between critical thinking skills and cognitive abilities.

One of the keys to success in problem-solving is determined by the acquisition of knowledge acquired during the didactical stage and clinical training, which refers to cognitive skill acquisition.[10,53] Clinical experience and practice of CDS participants seem to affect their diagnostic thinking or reasoning skills, as shown in the DTI overall scores. Knowledge and reasoning are closely related,[34,54] so it can be understood that there is a significant correlation between DTI and CAT measurement results (Table 4). Clinical reasoning skills are closely related to cognitive abilities, even though the association is relatively weak. The positivity of test results indicated that the better the students' cognitive abilities are, the better are their clinical reasoning skills.

Several factors differentiate novice from experts, with novices knowing less, and their knowledge is less structured and coherent, while they have insufficient strategies to access knowledge and use it.[46,49,55] This study clearly demonstrates that the acquisition of knowledge has an impact on clinical reasoning skills. Referring to the stage model of Dreyfus,[55] dental students can be divided into two groups based on their structure of knowledge, namely novices and

advanced beginners. Both showed differences in clinical reasoning skills and cognitive abilities, with the CDS as advanced beginners more superior to the UDS as a novice. The correlation analysis proved that the more knowledge acquired, the better clinical reasoning skills will be. In contrast to critical thinking skills, it is not the clinical science or knowledge that influences it but general knowledge.[6,56] This finding is shown in the results of the measurement of critical thinking skills in this study, which found no difference between the two groups. Critical thinking skills are intended for problem-solving and decision-making in everyday life.[56]

At the Faculty of Dentistry, Universitas Gadjah Mada, there are no courses that specifically teach these critical thinking and clinical reasoning skills. The nuances of traditional learning still overshadow the learning process, even though it has taken advantage of curriculum innovations. In the latest Indonesian Dentist Competency document,[36,57] it is assumed that applying 'logical, critical, and theoretical' thinking during education can create skillful and proficient dentists with measurable qualities. Some dental faculty incorporate these skills' components indirectly into courses delivered on a departmental basis, through a variety of learning and instructional methods. The assessment is solely on cognitive abilities that reflect academic achievement. This may have played a role in the study results which showed no difference in critical thinking skills between the two groups.

Clinical reasoning can be considered as critical thinking in clinical situations. Clinical knowledge and experience influence the development of clinical reasoning skills. The UDS as study participants underwent dental education with a traditional curriculum model which partly implemented student-centered learning. The procedural clinical knowledge is obtained through simulations between friends or practicum, and it is regarded as early clinical exposure for them. They have not met actual patients yet, nor faced their complaints, solved their problems, and made clinical decisions regarding their complaints. The clinical dental knowledge is obtained after they have graduated and enter clinical rotation. This delay may be seen in the study results which showed a significant difference in critical thinking skills between groups. The lack of clinical knowledge and experience by the UDS affects the measurement of their clinical reasoning skills. Generally, the CDS showed better clinical reasoning skills than the UDS participants.

The results of the measurements on cognitive abilities which refer to knowledge acquisition show some remarkable results. The CDS showed better cognitive abilities on clinical knowledge, while there were no differences in basic/biomedical knowledge between groups. The clinical experience provides a deep understanding of pathophysiological processes and clinical behavior, which were previously only studied in theory, schematics, or viewing the clinical picture during the didactic stage. Facing real-life problems directly with various dental patients will assist the CDS in clinical problem-solving and decision-making. This result is in accordance with the theory of medical expertise as discussed above.

The Limitations of This Study

This study was far from flawless, and some weaknesses that can be identified include study target or population, sampling method, sampling size, and generalizability of the resulting study. This study employs natural experimental methods, and was an observational study that was not randomized nor did the participants receive an intervention by the researchers. Instead, the participants in the sample population in natural experiments are allowed to be influenced by nature or factors outside of the researchers' control.[58] The natural conditions refer to the learning process engaged in by participants. The grouping of participants was non-randomized but based on the stages of learning, namely undergraduate students and clinical students. The natural experimental study has some disadvantages: a) no control over confounding variables, such as student personality, motivation, or social class; b) bias on a representative sample, where the groups may be dissimilar and nonhomogeneous because they are not randomly selected. This will be affecting the authenticity and generalizability of the study results; c) natural observations are less reliable, with no control of variables, which makes it difficult for another researcher to replicate the study. However,

there were some advantages of conducting the natural experimental study, i.e., the study process resembles a real-life situation, and compliance to ethical reasons related to human characteristics which are not subject to experimental manipulation. Regarding participant characteristics, dental students belong to the lowest level of medical expertise. Measurements on these three skills/abilities will show a more significant difference if observed at more diverse expertise levels. Therefore, these study results may be less than satisfactory. These weaknesses need to be considered in future research on critical thinking skills, clinical reasoning, and cognitive abilities.

CONCLUSIONS

The findings showed that the clinical reasoning skills and cognitive abilities of CDS are superior to UDS. Generally, the better the students' cognitive abilities are, the better are their clinical reasoning skills. Better cognitive abilities tend to improve clinical reasoning skills.

RECOMMENDATIONS

Dental institutions should incorporate the principles of critical thinking and clinical reasoning into their curriculum, and align them in every course to its level of education. The dental curriculum should provide adequate basic and biomedical knowledge that facilitates understanding of various clinical knowledge, as well as utilizing various learning methods, instructions, and assessments that emphasize critical thinking and clinical reasoning. Dental faculty should understand their role in teaching, training, and assessing students, emphasizing both active-learning principles in their learning process during the didactic as well as in clinical stage, which is aimed at graduating a future dentist who is clinically competent with satisfactory knowledge to provide optimal professional oral health care.

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COMPETING INTEREST

We have no competing interests, and there is no financial, commercial, legal, or professional relationship with other organizations, or with the people working with us, that could influence our study.

AUTHORS' CONTRIBUTION

Bernadetta Esti Chrismawaty – developing research proposal and managing the study design, collecting and analyzing data, and drafting of the manuscript and preparing figures and tables.

Gandes Retno Rahayu – reviewing the study design, directing data collection, analysing data, completing and revising the manuscript.

Ova Emilia – complementing the research method, reviewing data collection, analysing data and completing the manuscript.

Ika Dewi Ana - guiding to conduct the research, supervising data collection and analysis, and revising the manuscript.

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