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Student self-assessment of operative dentistry experiences : a time dependent exercise in best practice outcomes.

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STUDENT SELF-ASSESSMENT OF OPERATIVE DENTISTRY EXPERIENCES: A TIME DEPENDENT EXERCISE IN BEST PRACTICE OUTCOMES

By

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A Thesis Approved on

March 13th, 2017

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DEDICATION

This thesis is dedicated to my parents, Cornelius Timothius and Catherine Christina. Their constant encouragement and support has allowed me to make it to this point in my education.

I also want to thank my Mentor: Dr. Michael Metz. I appreciate his willingness to foster my curiosity and lead me through the research process.

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Dr. Randall Vaught, Thesis Committee Member: For continuing investment and interest in the progression of the project.

ABSTRACT

STUDENT SELF-ASSESSMENT OF OPERATIVE DENTISTRY EXPERIENCES : A TIME DEPENDENT EXERCISE IN BEST PRACTICE OUTCOMES

Celine Joyce Cornelius Timothius

March 13th, 2017

Purpose: The purpose of this project was to evaluate student self-assessment of operative dentistry experiences. Methods: First, a retrospective analysis of student self-assessment and faculty assessment grade sheets were evaluated for mean differences and correlations across time. Both preclinical (D2: n=120) and clinical (D3: n=120; D4: n=120) grades sheets were evaluated. Secondly, twenty-five (n=25) students from each of the D1, D2, D3 and D4 classes were asked to evaluate dentoform work. Twenty-five (n=25) operative calibrated faculty graded the same two dentoforms. Results: D2 student's self-assessment scores were significantly higher than the faculty assessment scores (t-test; $p<0.05$) and there was a negative correlation of scores ($r= -0.503$). D3 student's self-assessment scores were significantly higher than the faculty assessment scores (t-test; $p<0.05$) and there was a negative correlation of scores ($r= -0.235$). D4 student's self-assessment scores were not significantly different than the faculty assessment scores (t-test; $p>0.05$) and there was a positive correlation of scores ($r= 0.408$). On the prospective analysis, D1 dental students, D2 dental students and D3 dental students graded significantly higher (ANOVA; $p<0.05$) on the dentoform project than did the D4 dental students and faculty. There was an increasing correlation of scores directly related to experience (D1: $r= -0.120$; D2: $r= 0.255$; D3: $r= 0.352$; D4: $r= 0.689$). Conclusion(s): Student self-assessment is a learned process through experiential and continual encounters across time. The summative goal for all dental institutions is too provide students with the skills and knowledge to critical evaluate their work for self-directed learning.

KEY WORDS

Student Self-Assessment, Faculty Assessment, Operative Dentistry, Correlational Assessments, Critical Thinking

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INTRODUCTION AND LITERATURE REVIEW

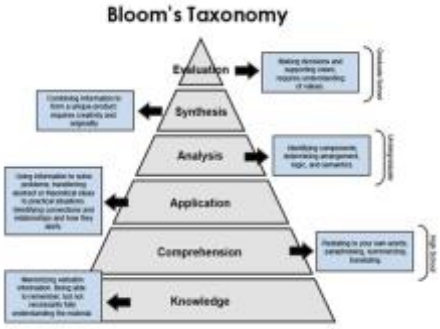
The Commission on Dental Accreditation (CODA) mandates through standard 2 (Educational Programs), specifically 2-10, that "Graduates must demonstrate the ability to self-assess, including the development of professional competencies and the demonstration of professional values and capacities associated with self-directed, lifelong learning."[1] It is then up to all dental schools to interpret this standard and provide some qualitative or quantitative data to suggest successful attainment.

Therefore, a prominent goal of student self-assessment development activities are to support integration of relevant, evidence-based self-directed learning consistent with the skills attainment, expected learner outcomes, and supporting strategies.[1-10] Student self-assessment is the cornerstone of learned skills to ensure optimal patient centered care learner outcomes.[11-15] A significant part of self-assessment with professional students is to provide foundational knowledge, attitude and skills for both formative and summative assessment of technical competence.[2-15] The idea of student self-assessment is not a new concept of critical evaluation in educational literature. Many research projects have focused on student self-assessment for improving student learning outcomes both quantitatively and qualitatively.[14] According to a recent systematic review article on student self-assessment published by Mays & Branch-Mays (2016),[14] missing from the current literature is retrospective evaluation of student self-assessment scores compared to faculty assessment scores across time from a single class using bracketed assessment forms. Also missing from the current literature is correlation data to validate the comparison of mean assessment scores. Additionally, missing from the current literature is prospective data from current students that can be used to validate the results obtained from the retrospective data.

Two conceptual educational models help us understand how learning outcomes or objectives relate to learners' professional development as they move along the novice to expertise continuum.[16-18]

1.BLOOM'S TAXONOMY OF EDUCATIONAL OBJECTIVES IN THE COGNITIVE DOMAIN, and

2.MILLER'S PYRAMID



Figures 1&2- Bloom's Taxonomy and Miller's Pyramid of Competence

The first is found in Bloom's Taxonomy of Educational Objectives in the Cognitive Domain (1956), which describes how learning objectives related to cognitive development increase in complexity as learners develop deeper understanding, start to apply this knowledge, and ultimately synthesize and evaluate what they have learned.[16] In 2001, former students of Bloom published a revised Taxonomy using verbs rather than Bloom' s original nouns.[17] These were also listed from low order thinking skills (LOTS) to high order thinking skills (HOTS) to represent the complex process of learning.[17] Another model that is particularly useful for thinking about learning outcomes in relation to assessment of clinical competence is Miller's (1990) pyramid.[18] This model is similar to Bloom's Taxonomy in that there is a marked shift from being able to demonstrate knowledge that underpins clinical competence to patient application. Learners' theory (intellectual skills), psychomotor skills and professional attitudes are synthesized and internalized into a seamless routine that can be carried out in different contexts.[16-18]

Across our dental school curricula, dental students are exposed to both pre-clinical and clinical operative dentistry courses where they receive formative instruction from various dental school faculty. The formative assessment of student performance on operative dentistry terminology, preparations and restorations begin in pre-clinical laboratory sessions through objective grading criteria located in an objective grading rubric. Novice students are initially exposed to new terminology, concepts and technical skills that they don't fully understand measured in millimeters. Due to this fledgling approach, novice students have a hard time discerning small details that can be detrimental to the longevity of direct restorations. Therefore, self-assessment is a learned

area of critical thinking honed through experiential and consistent exposure to various clinical scenarios.[6-9]

It is imperative to understand the progression of learner outcomes through consistent objectives so that calibrated and realistic expectations of our dental student's clinical experiences are established.[19] The progressive transformation of novice provider to competent clinician must include calibrated student self-assessment to ensure a deeper understanding of the knowledge, attitude and skills needed for patient centered care.[16-18] The progressive transformation from novice to competent health care providers should include student self-assessment scores that approach faculty assessment scores at the conclusion of their professional training. Not only should the assessment scores align between students and faculty, but exhibit some correlation by the end of student training.

The purpose of this research project was to evaluate the process of student self-assessment on operative dentistry skills at the University of Louisville Dental School. It is imperative that dental schools provide some quantifiable data to suggest students possess the ability to accurately self-assess as competent beginning practitioners upon graduation. The director for the division of clinical operative dentistry maintains a portfolio of formative and summative operative dentistry experiences used for assessment of clinical competence. Noted were possible inconsistency is student self-assessment following preclinical dentoform and clinical patient experiences when compared to faculty assessments at all levels of education. Therefore, the following research questions were used to guide this evaluation of student self-assessment across time: Is there a difference in the class of 2016 mean self-assessment scores at each of the D2, D3 and D4 year's courses compared to faculty assessment scores? Is there a correlation between self-assessment scores at each of the D2, D3 and D4 year's courses compared to faculty? Is there a difference in mean scores comparing D1, D2, D3 and D4 student self-assessment scores to faculty assessment scores on a single preparation and restoration? Is there a correlation between the D1, D2, D3, D4 and faculty scores on a dentoform evaluation.

HYPOTHESIS

Student self-assessment is a learned process through experiential and continual encounters across time. As technical experience increases throughout skills development, assessment grades from D4 students will approach faculty assessments scores as compared to D1, D2 and D3 students.

MATERIALS AND METHODS

Sample

This study was approved by the University of Louisville Institutional Review Board (IRB): IRB Tracking # 16.0683. The research design for this project was twofold: First, a retrospective between-groups analysis of student self-assessment and faculty assessment grade sheets were evaluated for mean differences in overall scores and correlation coefficients. For this portion of the evaluation, both preclinical (D2: n=120) and clinical (D3: n=120; D4: n=120) grades sheets were evaluated. Secondly, twenty-five (n=25) consented students were randomly selected from each of the D1, D2, D3 and D4 classes to total one hundred students (n=100). These students were asked to evaluate a #19 DO preparation and amalgam restoration (two separate dentoforms) as if they completed them. Additionally, twenty-five (n=25) consented operative calibrated faculty from the department of general dentistry graded the same two dentoforms. Each of the five groups were compared for overall mean differences in scores and correlation coefficients as a between-groups analysis.

Grading Assessment

Students are asked to perform self-assessment on all formative and summative preclinical and clinical operative dentistry experiences prior to faculty assessments. Our institution defines formative assessment as informal and formal feedback during the learning process to provide information to improve a student's knowledge, skills, attitudes and values. Therefore, it provides information to the teacher and student on the student's development at a particular time. Additionally, our institution defines summative assessment as whether the student has achieved the skills necessary to advance professionally and act independently through self-directed learning. The evaluation form is bracketed across the preclinical and clinical operative dentistry curriculum so that students are continually exposed to a consistent form. Initially, students are given exercises in their preclinical operative dentistry courses in using the grading rubric to assess pre-prepared cavity preparations. Over time, students and faculty alike are provided and calibrated continually on an operative dentistry grading rubric that intimately corresponds to the grading assessment sheets. As such, accuracy of the student self-assessment becomes part of the faculty assessment for the

students overall grade. Both the student and faculty assess all operative dentistry procedures so that a dialogue can occur in areas of possible non-agreement to provide a profound teaching experience for improving student self-directed learning.

The assessment sheets are broken down into three areas of evaluation: 1. Overall Experience, 2. Preparation Design Principles and 3. Restoration Design Principles. (Table 1). Each faculty member and student completes the entire grade form for each individual operative experience. Students are asked to self-assess on the far right column prior to having the faculty assess under the faculty score column on all formative experiences. In the overall experience section, graded are preparedness, clinical judgment, critical thinking/ self-assessment and professionalism. In the preparation design principles section, graded are outline form, retention form, resistance form and terminology/communication. In the restoration design principle section, graded are anatomical form, marginal integrity, proximal contact placement and embrasure form. Each of the three sections contain critical errors in which the experience at hand becomes unsuccessful and recorded as a zero. Some of the critical errors are patient specific not able to be simulated on dentoforms in the preclinical courses. In these areas like inadequate anesthesia and caries removal, students are questioned orally about concepts associated with each. Their responses are graded according to the course rubric and self-assessed. The first course encountered by the entering D1 students is infection control protocol with associated competencies of understanding. Therefore, all preclinical summative competency examinations are patient simulated donning all infection control protocol and timed for efficiency.

Overall academic achievement scores from both formative and summative experiences are calculated using the following grading scale: 3= exceptional, 2= acceptable and 0= unacceptable. Therefore, a mean overall score must exceed a 2 (acceptable) to be considered a successful experience. In each of the three sections there are four areas of assessment resulting in twelve overall grades. Each of the twelve scores are weighted equally in determining the overall score for the experience. For both formative and summative operative dentistry experiences, any critical error denoted by an asterisks results in a failure for that overall experience and recorded as a zero. During any formative experience in both preclinical and clinical courses, a zero score (unacceptable) can be calculated into the overall grade but the mean score must be greater than 2 (acceptable). During all summative competency examinations in both preclinical and clinical courses, a zero grade recorded for any section results in an unsuccessful experience and recorded as a zero. So, during summative examinations, students can't fail one section of the grade sheet and pass the overall examination experience. A mean score is

calculated by simply adding the twelve scores and dividing by twelve. For example, if a student get a score of 2 (acceptable) in each of the twelve grading spots, their total score is twenty-four divided by twelve equaling 2. This then can be easily converted to percentages of total points. At our institution, all summative competency examinations require two independent graders with a third available for split decisions. Therefore, student's complete two grade sheets; one for each grader for all summative operative competency dentistry examinations. The mean scores from each of the two individual score sheets are averaged for an overall achievement score.

Calibration

Students receive routine calibration on both the grade from and rubric beginning in their D1 preclinical operative dentistry course. Students participate in active learning techniques and interactive group grading initially using pre-prepped and pre-restored procedures. Students then move to audience response system quizzes on both dentoform and clinical slides to further hone their assessment techniques. Students then move to the simulation laboratory next where they learn to perform various direct operative dentistry procedures and self-assess their own work over their D1 and D2 years. Students enter clinical care during their D3 and D4 years where they continue to self-assess on clinical procedures during patient care.

All fifty-six general dentistry faculty (part-time and full-time) in the department receive quarterly calibration training using an audience response system to include usage of the grade form and rubric. Scoring calibration is performed on dentoforms and patient cases, recorded and evaluated for areas of disagreement. Individual faculty are assigned a specific audience response system that is trackable by the operative dentistry discipline coordinator. The discipline coordinator and director of clinical operative dentistry performs routine clinical assessments of observer agreement (Cohen's Kappa) among faculty performing formative and summative evaluations. All general dentistry faculty can perform formative assessment of student work in both the preclinical and clinical operative dentistry courses. During formative assessments there is typically one grader, so the discipline coordinator chooses random operative patient based procedures to act as a second grader for observer agreement evaluation. However, there are ten calibrated full-time faculty that perform summative competency assessments in all preclinical and clinical operative dentistry courses. These ten individuals that includes the discipline coordinator for clinical operative dentistry are grouped in many combinations of two depending on the comprehensive clinic schedule. Various combinations of the ten summative competency graders allows for broader observer agreement data to be collected and evaluated.

Participants

For the retrospective portion of this study, grade sheets were pulled from locked storage by the discipline coordinator of both preclinical and clinical operative dentistry from the class of 2016 that enrolled 120 students. One hundred twenty (n=120) experiences were selected from the final objective structured clinical examination (OSCE) portion of the D2 preclinical operative dentistry II course for evaluation prior to entering patient care. These contained one hundred twenty individual D2 student self-assessment scores and one hundred twenty averaged faculty assessment (two faculty per score sheet) scores on an ideal class II MO preparation and restoration tooth #13. All three sections of the grade sheets were scored by both the student and the two faculty members. The two faculty graders are paired randomly from the ten available and assigned a pod of 24 students grading 12 students per day over two days. One hundred twenty (n=120) D3 student clinical experiences were selected from their final summative competency examination completing clinical operative dentistry I. These contained one hundred twenty individual D3 self-assessment scores and one hundred twenty averaged faculty assessment (two faculty per score sheet) scores of various types of class II and class III competency examinations. All three sections of the grade sheets were scored by both the student and the two faculty members. The two faculty graders were paired randomly from the ten available. One hundred twenty (n=120) D4 student clinical experiences were selected from their final summative competency examination completing clinical operative dentistry II prior to graduating. These contained one hundred twenty individual D4 self-assessment scores and one hundred twenty averaged faculty assessment (two faculty per score sheet) scores of various types of class II and class III competency examinations. All three sections of the grade sheets were scored by both the student and the two faculty members. The two faculty graders were paired randomly from the ten available. Grade forms remained anonymous at all times and used only to gather data for this portion of the study. The forms were refiled into a locked cabinet for storage per university guidelines. Additionally, no names were recorded as group means and correlations were evaluated, not individual scores.

For the prospective portion of this study, a convenience sample of twenty-five (n=25) students were randomly selected from each of the D1, D2, D3 and D4 classes to total one hundred students (n=100). These students were asked to evaluate a #19 DO preparation and amalgam restoration (two separate dentoforms) as if they completed them. Additionally, twenty-five (n=25) operative calibrated faculty (not from the ten competency graders) from the department of general dentistry graded the same two dentoforms. For this portion of the study, students and faculty completed the last two sections of the grade sheet (Table 1): cavity preparation principles and

restoration design principles. Participants did not complete the overall experience section as they did not so the work. The remaining 8 scores were evenly weighted for this portion of the evaluation. All participants were provide a preamble approved by the IRB as consent to participate in this study. The risks associated with this study are minimal, however, students and faculty could withdraw from the study at any time without repercussions. The discipline coordinator of clinical operative dentistry both prepared and restored the dentoform tooth #19-DO for and with dental amalgam. Noted deficiencies were incorporated into both the preparation and restoration. For the preparation, the axial-pulpal line angle was not rounded enough compromising resistance form, there was an extremely conservative retention groove placed in the distal-buccal proximal wall compromising retention form and the distal-lingual contact in the proximal wall was not broken enough. For the restoration, the proximal contact was placed too lingual, the distal marginal ridge was not in occlusal contact and the distal pit anatomical form was slightly too deep. Please note that none of the deficiencies for both the preparation and the restoration were critical errors using our grading assessment criteria rubric. All groups were blinded to each other scores during this part of the evaluation. The director of clinical operative dentistry was blinded to both students and faculty scoring as they only declared their group status on the evaluation form.

Data Collection and Analysis

For the retrospective portion of this study, grade sheets were pulled from storage by the discipline coordinator of both preclinical and clinical operative dentistry from the class of 2016. The raw data was imported into SPSS (Statistical Package for the Social Sciences, IBM, Chicago, IL) for descriptive and inferential statistical reporting and analysis. For the summative D2 preclinical course (n=120), D3 clinical I course (n=120) and D4 clinical course II (n=120), an independent t-test was used to compare student self-assessment mean scores to faculty assessment mean scores within each course. The dependent variables used for this evaluation were the assessment scores given by both the students and faculty. The independent variables used for this evaluation were the group assignment of scores, student or faculty. Type I error rate was set was set at $p<0.05$ as a significant difference in mean values disproving the null hypothesis. An A Priori power analysis was performed to determine the appropriate sample size for this evaluation. With a type I error rate of $p<.05$, a type II error rate of 0.8 and a moderate effect size of 0.5, the power analysis determined that the sample size needed was fifty-two (N=52) for population inference. Additionally, correlations were sought between student self-assessment scores and faculty assessment scores using linear regression for each individual course. Faculty

assessment scores were used as the dependent variable and the student self-assessment scores were used as the independent variable. Type I error rate was set at $p<0.05$ as a significant correlation between variables disproving the null hypothesis. The strength of the relationships used the following values: strong positive correlation ≥ 0.75; moderate positive correlation 0.74 – 0.51; weak positive correlation 0.50 - 0.25; marginal positive correlation 0.24 to 0.10; no correlation ≤ 0.09. The same value ranges will be used for negative correlations in the negative range. Reported for each regression model was the coefficient of determination (r^2).

For the prospective portion of this study, one hundred (N=100) dental students (n=25 from each year group) were asked to grade a preparation and restoration completed by the director for the division of clinical operative dentistry. Additionally, twenty five (n=25) calibrated operative faculty assessed the same two dentoforms. The raw data was imported into SPSS for descriptive and inferential statistical reporting and analysis. A univariate analysis of variance (ANOVA) was used to compare student assessment mean scores to faculty assessment mean scores. The dependent variable used for this evaluation was the assessment scores given to the dentoform project. The independent variables used for this evaluation were the group assignment of scores; D1 students, D2 students, D3 students, D4 students or faculty. Type I error rate was set was set at $p<0.05$ as a significant difference in mean values disproving the null hypothesis. An A Priori power analysis was performed to determine the appropriate sample size for this evaluation. With a type I error rate of $p<.05$, a type II error rate of 0.8 and a moderate effect size of 0.5, the power analysis determined that the sample size needed was twenty-two (N=22) for population inference. Levene's test of equality of error variances was performed to test the null hypothesis that the error variance of the dependent variable is equal across groups. If the Levene's test is significant, then the variances in the different groups are different (your groups are not homogenous). A test of the main effect using the Bonferroni correction was performed. Bonferroni correction is a method used to counteract the problem of multiple comparisons and to control the familywise type II error rate. Additionally, correlations were sought between student assessment scores and faculty assessment scores using multiple linear regression. Faculty assessment scores were used as the dependent variable and the student self-assessment scores were used as the independent variable. Type I error rate was set at $p<0.05$ as a significant correlation between variables disproving the null hypothesis. The strength of the relationships used the following values: strong positive correlation ≥ 0.75; moderate positive correlation 0.74 – 0.51; weak positive correlation 0.50 - 0.25; marginal positive correlation 0.24 to 0.10; no correlation ≤ 0.09. The same value ranges will be used for negative correlations in the negative

range. Reported for the regression model was the coefficient of determination (r^2).

Null Hypotheses Tested

- Null Hypothesis RQ 1: There will be no significant mean difference in D2, D3 or D4 student self-assessment scores compared to faculty assessment scores in each course.
- Null Hypothesis RQ 2: There will be no significant correlation in predicting D2, D3 or D4 student self-assessment scores from faculty assessment scores in each course.
- Null Hypothesis RQ 3: There will be no significant mean difference in D1, D2, D3, D4 and faculty assessment scores compared to one another on the dentoform project.
- Null Hypothesis RQ 4: There will be no significant correlation in predicting D1, D2, D3 and D4 assessment scores from faculty assessment scores on the dentoform project.

RESULTS

D2 Preclinical Operative Dentistry II Course

Descriptive Statistics: There is general trend in the descriptive data that the D2 dental student's self-assessment scores (87.35 ± 3.29; n=120) were higher than the faculty assessment scores (79.06 ± 4.75; n=120) on an OSCE summative dentoform competency examination (Class II MO-13 resin composite). Table 2.

Inferential Statistics: An independent t-test determined a statistically significant difference in mean scores ($p<0.05$) comparing the D2 student self-assessment scores (n=120) and the faculty assessment scores (n=120). The D2 student's self-assessment scores were significantly higher than the faculty assessment scores. The null hypothesis for research question 1 was rejected. Table 2. Using linear regression to predict student self-assessment scores from faculty assessment scores, there was a moderate negative correlation between scores ($r= -0.503$). The coefficient of determination ($r^2= 0.253$) determined that 25.3% of the variance in student self-assessment scores can be explained by faculty assessment scores. The analysis of variance (ANOVA) for the model was significant $F=5.061$ with $p<0.05$. The null hypothesis for research question 2 was rejected. Table 3.

D3 Clinical Operative Dentistry I Course

Descriptive Statistics: There is general trend in the descriptive data that the D3 dental student's self-assessment scores (85.33 ± 4.89; n=120) were higher than the faculty assessment scores (77.54 ± 4.81; n=120) on a summative patient based competency examination. Table 2.

Inferential Statistics: An independent t-test determined a statistically significant difference in mean scores ($p<0.05$) comparing the D3 student self-assessment scores (n=120) and the faculty assessment scores (n=120). The D3 student's self-assessment scores were significantly higher than the faculty assessment scores. The null hypothesis for research question 1 was rejected. Table 2. Using linear regression to predict student self-assessment scores from faculty assessment scores, there was a marginal negative correlation between scores ($r= -0.235$). The coefficient of determination ($r^2=0.055$) determined that 5.5% of the variance in student self-assessment scores can be explained by faculty assessment scores. The analysis of variance

(ANOVA) for the model was significant F=54.954 with $p<0.05$. The null hypothesis for research question 2 was rejected. Table 3.

D4 Clinical Operative Dentistry II Course

Descriptive Statistics: There is general trend in the descriptive data that the D4 dental student's self-assessment scores (81.84 ± 5.05; n=120) were higher than the faculty assessment scores (79.45 ± 4.81; n=120) on a summative patient based competency examination. Table 2.

Inferential Statistics: An independent t-test determined there was not a statistically significant difference in mean scores ($p>0.05$) comparing the D4 student self-assessment scores (n=120) and the faculty assessment scores (n=120). The D4 student's self-assessment scores were not significantly different than the faculty assessment scores. The null hypothesis for research question 1 was not rejected. Table 2. Using linear regression to predict student self-assessment scores from faculty assessment scores, there was a moderate positive correlation between scores (r= 0.408). The coefficient of determination (r^2= 0.166) determined that on 17% of the variance in student self-assessment scores can be explained by faculty assessment scores. The analysis of variance (ANOVA) for the model was significant F=116.60 with $p<0.05$. The null hypothesis for research question 2 was rejected. Table 3.

Student and Faculty Dentoform Evaluation

Descriptive Statistics: There is a general trend in the descriptive data showing that newer students seemed to assess the highest with the least technical experience. As technical experience increases throughout skills development, assessment grades from student seem to approach faculty assessments scores. D1 dental students graded the highest (93.52 ± 1.71; n=25), followed by D2 dental students (90.44 ± 2.31; n=25), followed by D3 dental students (86.84 ± 1.43; n=25). The D4 dental students graded very similarly to the faculty, (83.72 ± 2.96; n=25) and (82.16 ± 1.92; n=25) respectively. Table 4.

Inferential Statistics: The Levene's test of equality was not significant so the five groups being compared were considered homogenous with similar variance error rates; $F(4,120) = 2.618$ with $p>0.05$. A univariate analysis of variance (ANOVA) between subjects evaluation determined a significant main effect across groups; F= 120.388 with $p<0.05$. The effect size was determined to be large at .801. Based on the findings of a significant main effect across groups, a pairwise comparison was performed using the Bonferroni correction to control type I error rates. It was determined that the D1 dental students, D2 dental students and D3 dental students graded significantly higher ($p<0.05$) on the dentoform project than did the D4 dental students and faculty. There was no statistically significant difference in the assessment scores between

the D4 dental students and faculty ($p>0.05$). Therefore, the null hypothesis was rejected for research question 3. Table 4. Using multiple linear regression

to predict student assessment scores from faculty assessment scores, there was a range of correlations between scores. When compared to the faculty, the D1 students assessments scores were negatively correlated ($r= -0.120$), the D2 students assessment scores were positively correlated ($r= 0.255$), the D3 students assessment scores were positively correlated ($r= 0.352$) and the D4 students assessment scores were positively correlated ($r= 0.689$). The coefficients of determination (D1: $r^2= 0.0144$; D2: $r^2= 0.065$; D3: $r^2= 0.123$; D4: $r^2= 0.474$) determined that 1.4%, 6.5%, 12.3% and 47.4% (respectively) of the variance in student self-assessment scores can be explained by faculty assessment scores. As operative dentistry experience increased for the students, the assessment scores became more positively correlated compared to faculty. The analysis of variance (ANOVA) for the model was significant $F=85.9$ with $p<0.05$. The null hypothesis for research question 4 was rejected. Table 5.

DISCUSSION

The results from the retrospective portion of this study evaluating a single class (2016) of one hundred twenty dental students' shows that progressive skills, attitude and knowledge are needed to provide a profound self-assessment of operative dentistry procedures. Following Bloom's Taxonomy (1956), entry level students have a difficult time visualizing the minute details required for a successful long term direct restoration.[16] The data shows that novice students tend to over assess their technical skills when compared to faculty assessments. It is only through experiential repetition that students can learn the nuances of cavity preparation and restoration design. In asking novice students to perform higher order thoughts like "evaluation" referencing Blooms Taxonomy of educational objective, errors should occur as those skills are honed.[16,17] Especially if lower order thoughts like "understanding" and "application" are confused.[16,17] It was interesting to look at dental students' progression through the operative dentistry curriculum as they gained valuable experiences in critical thinking. For the class of 2016, both Bloom's original taxonomy of Educational Objectives and the revised Taxonomy for Teaching, Learning and Assessment are evident across time.[16,17] Anderson et al. (2001) and his team revised the original Bloom's Taxonomy (1956) to include action verbs from lower order thoughts to higher order thoughts.[17] In asking students to provide accurate self-assessment of their work, students are performing higher order cognitive thoughts like "differentiating, critiquing and generating."[17] Therefore, self-assessment is a crucial part of critical thinking in a higher cognitive domain to improve learner outcomes and self-directed learning.[17]

As D2 dental students, the class of 2016 assessed themselves significantly higher on their summative OSCE examination restoring a #13-DO for resin composite compared to the faculty. Additionally, there a moderate negative correlation between the two sets of scores but the model was determined to be significant. As novice students still working on dentoforms, they are learning the foundational knowledge, attitude and skills to critically evaluate their own work. In essence, the novice students are being asked to perform higher order thoughts without mastery of the lower order cognition.[17,18] As D3 dental students, the class of 2016 again assessed themselves significantly higher on their final summative clinical patient-based competency examinations compared to the faculty. The correlation of scores was only slightly higher than their D2 course but became positive. The progressive transformation from dentoform assessments to patient based

assessments should be gradual as seen here. The base knowledge to which they have become accustomed to evaluate in the preclinical course has not added the variable of patient interaction. Students are transitioning to patient management skills, infection control protocol, time management skills and patient compliance issues. As D4 dental students with twenty-four months of clinical care, the class of 2016 assessed themselves vary similarly when compared to faculty. The correlation of the scores were significant with a moderate positive correlation. It appears from the data that dental students need crucial experiential time to develop profound cognitive processes in the higher order for accurate self-assessment. Again, the progressive transformation of novice to competent provider must include accurate self-assessment. The students must hone their critical thinking skills as sharpened by faculty across time. The scores obtained from the class of 2016 could not be compared over their three years of dental education as there were varying summative competency assessments from each year evaluated. This is why each course was looked at individually. However, the common variable shared was that the same assessment forms were used following a standardized rubric in all courses.

The results from the prospective portion of this study partially validated the finding from the class of 2016. Please recall for this portion of the study that only the cavity preparation principles and restoration design principles categories were scored. The overall experience category was not scored so there should be caution in directly comparing the retrospective and prospective studies. However, this does provide some insight into the ability of students to discern minute details in technical application across time of experience. Various groups with varying operative dentistry experience were asked to evaluate a #19 DO preparation and amalgam restoration (two separate dentoforms) with noted minute deficiencies. The faculty and D4 dental students were able to better detect the minute deficiencies through experiential practice and grade similarly. However, the less experienced students graded significantly higher when compared to the D4 dental students and faculty. The correlation of grades become more positive as clinical experience was obtained. Again, asking novice students to assess in higher order cognitive domains will result in error when compared to more experienced providers.[16-18] One can see from the data that students can reach higher order cognitive thought processes when compared to faculty with continual exposure to minute details across time.[16-18]

As aforementioned, the grading sheets at our institution for preclinical and clinical operative dentistry experiences are evenly weighted across three sections: 1. Overall Experience 2. Preparation Design Principles 3. Restoration Design Principles. Our institution finds this approach advantageous in that students learn that all aspects of the operative dentistry

experience are crucial in promoting self-directed learning. Having critical errors and equal weighting in all three categories reinforces the notion that technical competence is only a portion of assessing overall competence. For example, students that are technically sound with good operating skills in preparation design and restoration placement should fail a summative patient-based operative competency examination if they violate infection control protocol, act unprofessional or present unprepared. Another example, students who display excellent overall management of the patient with a perfect final direct restoration should fail a summative patient-based operative competency examination for grossly overextended the outline of preparation without approved modifications, lack of primary retention form or poor resistance form. For these reasons, a zero score for any one of the three categories or a critical error in any one of the three categories results in a failure of the experience for summative examinations. Many more examples could be presented as justification for equal weighting the grading sheet at our institution. Some may argue that the preparation design principles are the most difficult for the student to master and therefore should be weighted more on grading sheets. The notion of heavily weighting the preparation section may work in a beginning preclinical operative dentistry course but may portray the wrong message to the student. In promoting self-directed learning, it is important for students to see value in all aspects of patient care to include professionalism, critical thinking and self-assessment. It is for these reasons that the grade sheet carries equal weigh in grading across all three sections with associated critical errors at our institution.

Anecdotally, the mean score differences reported for the class of 2016 in their D2 and D3 years compared to faculty were distributed evenly across all three categories on the grade sheet. Although not looked at as a primary outcome of this study, it is important to disclose this information. In the overall experience category, students had a tendency to initially overinflate self-assessment grades in critical thinking and preparedness. In preparation design principles section, most students had a tendency to initially overinflate self-assessment grades in outline form and retention form. In the restoration design principles section, students had a tendency to initially overinflate self-assessment grades in anatomical form and proximal contact placement. For the class of 2016 in their D4 year, the students began to score themselves closer to faculty scores in all categories of the grade sheet. The mean score differences reported for the dentoform activity were also evenly distributed across both categories graded; Preparation Design Principles and Restoration Design Principles. D1, D2 and D3 students overinflated theirs assessments on the dentoform exercise not being able to easily discern the incorporated noted deficiencies.

The results for this study address many of the concerns brought forward within the literature review and the systematic review published by Mays & Branch-Mays.[14] Self-assessment forms are bracketed across both the preclinical and clinical operative dentistry curriculum using the same grading rubric. Students and faculty alike receive continual calibration training on the grading rubric to ensure an adequate depth of understanding to its practical application.[19] Data was extracted for one class (class of 2016) across three years of their operative dentistry curriculum to include both preclinical and clinical self-assessments. Mean group score comparisons were validated with correlation coefficients to see student self-assessment progress across time. Additionally, a snapshot of student and faculty application knowledge of the grading rubric was performed to validate the data extracted from the class of 2016. This comparative data validated that student self-assessment is a progressive learned experience across continual application receiving adequate calibration.

Student self-assessment is a learned trait in critical thinking and essential for teaching self-directed lifelong learning.[20,21] Students and faculty alike should be provided clear expectations and calibration of some objective grading assessment rubric that they all clearly understand.[19,22,23] A centralized calibration program for any dental discipline is the nucleus that feeds to the success of student self-assessment and self-directed learning.[19] If a dental school is successful in these goals, then quantifiable data should validate any program. Although CODA mandates that students possess the ability to accurately self-assess upon graduation,[1] it is more important that students understand the ramifications of poor clinical outcomes associated with not being able to detect critical errors. If we as dental educators can arm students with the knowledge, attitude and skills to understand the need for accurate self-assessment, only then we can truly graduate competent beginning practitioners. The greatest struggle we face as dental educators are students that can't accurately self-assess and never become aware of the minute details to improve outcomes. In our institutional experience, these students will remain incompetent until they have the ability to assess in higher order cognitive domains and eliminate critical errors from their practice.[16,17] At our institution, students that struggle to accurately learn or demonstrate self-assessment are put through extensive remediation until a comfort level can be achieved by the operative dentistry discipline coordinator. Students that continually struggle with understanding the importance and the awareness of self-assessment after extensive remediation may be withdrawn from the dental school.

In the transparency of including the grade form, it must be noted that this instrument is not being solicited as the gold standard for operative dentistry assessment. The validity and reliability of the instrument are current under

investigation. As for now, this assessment form is the institutions interpretation of CODA standards in self-assessment and attainment of promoting lifelong self-directed learning in operative dentistry. Changes may be necessary to this instrument as the dental school moves into the future and CODA standards change.

It is possible that other confounding variables could be the reason for the results obtained in this study. The authors are fully aware that grading rubrics and grading forms across US dental schools vary significantly. Therefore mean scores and correlations may vary from school to school. This is a very sample specific study and may not be generalizable to the population. An A Priori power analysis was done to determine the appropriate sample size considering effect size, type I error and type II error. Statistically, type I errors were controlled for using Bonferroni correction and tested assumptions during the univariate ANOVA comparing mean assessment scores. Correlational data was used to validate and compare to group mean scores. It is important to note that correlation does not imply causality; it simple suggests a relationship between data.

CONCLUSION

Student self-assessment is a learned process through experiential and continual encounters across time. The ability of students to assess in higher cognitive domains provide a more accurate assessment of their work. The summative end goal for all dental institutions is too provide students with the attitude, skills and knowledge to critical evaluate their work for lifelong self-directed learning. The data suggests that the University of Louisville is providing an environment for dental students to progressively learn how to perform self-assessment and hopefully achieve the understanding for lifelong self-directed learning.

TABLES

Table 1: Bracketed Operative Dentistry Grading Sheet

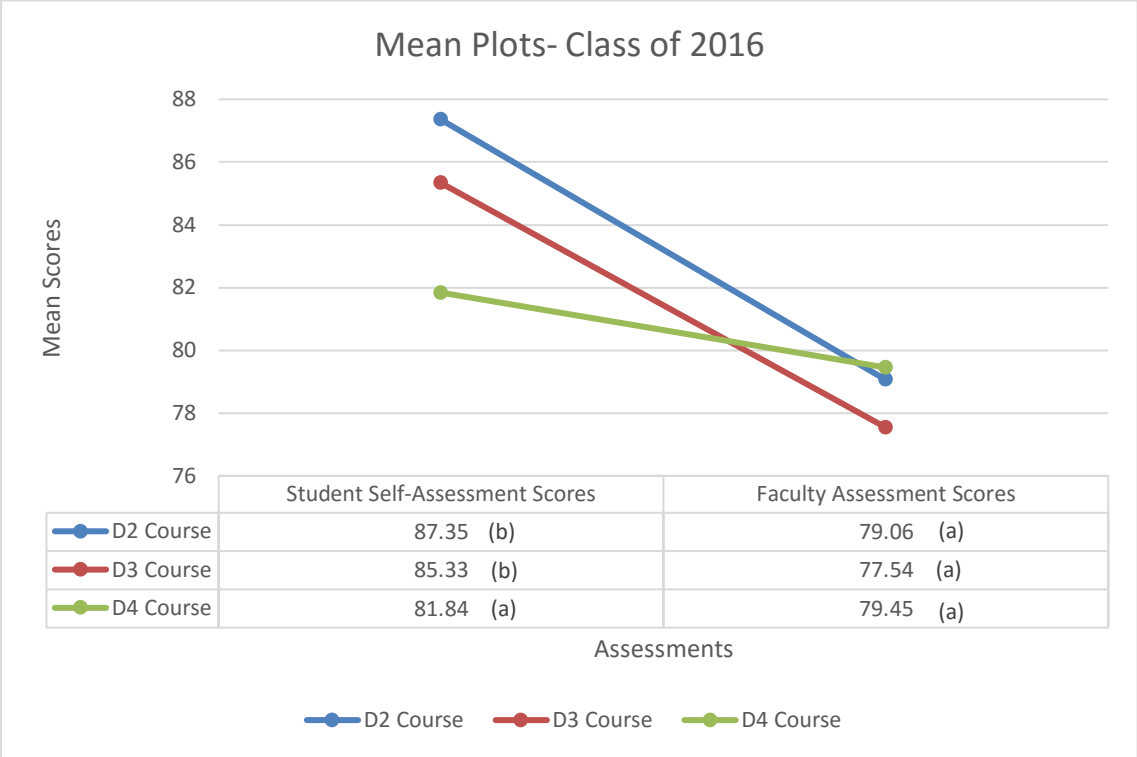
GDOM 834/846: CLINICAL OPERATIVE EVALUATION AND COMPETENCY SHEET

Student:		**Tooth #**	
Group:		**CDT Code**	
Date:		**Classification**	
Instructor:		**Surfaces**	
		Competency Exam?	☐ YES ☐ NO
		Restoration Type:	☐ Amalgam ☐ Composite

CATEGORY	COMMENTS	FACULTY SCORE			STUDENT SCORE		
Overall Experience							
Preparedness (Intellectual Autonomy)		3	2	0	3	2	0
Clinical Judgment (Confidence in Reasoning)		3	2	0	3	2	0
Critical Thinking and Self-Assessment		3	2	0	3	2	0
Professionalism (Intellectual Integrity)		3	2	0	3	2	0
*Infection Control Violations		YES			YES		
*Time Management		YES			YES		
Cavity Preparation							
Retention Form		3	2	0	3	2	0
Outline Form		3	2	0	3	2	0
Resistance Form		3	2	0	3	2	0
Terminology & Communication		3	2	0	3	2	0
*Inadequate Local Anesthesia		YES			YES		
*Inadequate Rubber Dam Isolation		YES			YES		
*Caries Remaining		YES			YES		
*Iatrogenic Pulp Exposure		YES			YES		
*Liner poorly placed or not Requested		YES			YES		
*Extensive Hard or Soft Tissue damage		YES			YES		
Restoration							
Anatomical Form and Esthetics		3	2	0	3	2	0
Embrasure Form		3	2	0	3	2	0
Proximal Contact Strength and Placement		3	2	0	3	2	0
Cavosurface Margin Integrity		3	2	0	3	2	0
*Open/Short Margin or Material Voids		YES			YES		
*Open Proximal Contact		YES			YES		
*Proximal Overhang		YES			YES		
*Hyper-Occlusion		YES			YES		
*Extensive Hard or Soft Tissue Damage		YES			YES		
*Circled "Yes" = Critical Error Grades: 3= Exceptional, 2= Acceptable, 0=Unacceptable AVERAGE		/12			/12		

Appendix I [redacted] 12 April, 2016

Table 2: Descriptive Statistics and Mean Score Plots for Class of 2016 per Course



	Student Self-Assessment Scores	Faculty Assessment Scores
D2 Course	87.35 (b)	79.06 (a)
D3 Course	85.33 (b)	77.54 (a)
D4 Course	81.84 (a)	79.45 (a)

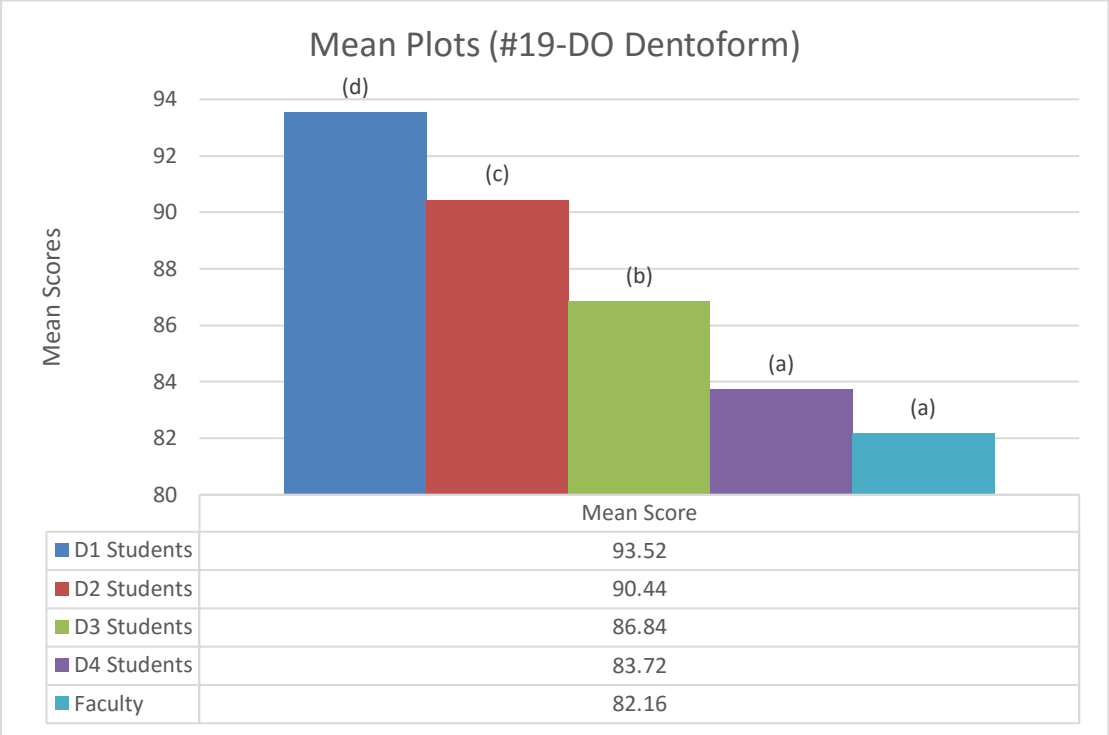
Different lower case letters within each course represent significant different mean values using an independent t-test ($p < 0.05$; n=120 per group).

Table 3: Correlation Coefficients for the Class of 2016 per Course

	D2 Faculty Assessment Scores	D3 Faculty Assessment Scores	D4 Faculty Assessment Scores
D2 Student Self-Assessment Scores	-0.503*		
D3 Student Self-Assessment Scores		-0.235*	
D4 Student Self-Assessment Scores			0.408*

*Correlational models using linear regression within each course were significant (ANOVA; $p < 0.05$; n=120 per group).

Table 4: Descriptive Statistics and Mean Score Plots for Dentoform Assessment



	Mean Score
D1 Students	93.52
D2 Students	90.44
D3 Students	86.84
D4 Students	83.72
Faculty	82.16

*Different lower case letters represent significant different mean values using a pairwise comparison with Bonferroni correction (ANOVA; $p < 0.05$; n=25 per group).

Table 5: Correlation Coefficients for Dentoform Assessment #19

	D1 Scores	D2 Scores	D3 Scores	D4 Scores	Faculty Scores
D1 Scores	1.00				-0.120*
D2 Scores		1.00			0.255*
D3 Scores			1.00		0.352*
D4 Scores				1.00	0.689*
Faculty Scores	-0.120*	0.255*	0.352*	0.689*	1.00

*Correlational models using multiple linear regression was significant (ANOVA; $p < 0.05$; n=25 per group).

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