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Comparing instructional techniques on memory retention, retrieval, application and self-efficacy of grading criteria used for student self-assessment.

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COMPARING INSTRUCTIONAL TECHINIQUES ON MEMORY RETENTION,
RETRIEVAL, APPLICATION AND SELF-EFFICACY OF GRADING CRITERIA
USED FOR STUDENT SELF-ASSESSMENT

By

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DEDICATION

This dissertation is dedicated to my wife and children

Cynthia Jayne Metz, Ph.D.

and

Parker David Metz

and

Zoey Adaline Metz

who have given me strength and perseverance following my dreams.

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ABSTRACT

COMPARING INSTRUCTIONAL TECHINIQUES ON MEMORY RETENTION, RETREIVAL, APPLICATION AND SELF-EFFICACY OF GRADING CRITERIA USED FOR STUDENT SELF-ASSESSMENT

Michael J. Metz

May 01, 2021

This dissertation was an exploration on how engagement (ENG) and spaced retrieval practice (SRP) could benefit students acquiring self-assessment skills in dental education. More specifically, how ENG and SRP could enhance memory retention, retrieval, application and self-efficacy of students learning grading criteria for self-assessment in preclinical operative dentistry. The University of Louisville Dental School (ULSD) currently uses a traditional, passive instructional technique with students learning self-assessment skills without ENG or SRP. The use of a traditional lecture directly conflicts with calls from governing agencies in establishing professional competencies in dental education. Calls requiring dental school curricula to employ evidence-based instruction techniques, student-centered learning and creating life-long learners.

One hundred and twenty (n=120) D1 dental students were randomly assigned to one of four treatment conditions (n=30) in this experimental 2X2 research study: no

ENG/ no SRP (control); no ENG/ SRP; ENG/no SRP; ENG/ SRP. Therefore, this study had two factors (independent variables) each with two levels: Factor A (level of engagement), No ENG/ ENG; Factor B (use of SRP), No SRP/ SRP. Outcomes assessment for information retention and retrieval was evaluated using a thirty (30) question multiple-choice examination four weeks post intervention. For information retention, retrieval and application, a hands-on dentoform activity was scored six-week post intervention. Lastly, student self-reported confidence level scores in using learned information during patient care were gathered six weeks post intervention.

The results indicated a significant main effect for both ENG and SRP on memory retention, retrieval, application and self-efficacy for students learning self-assessment skills. However, ENG had a larger effect than SRP on all three outcome assessments. Additionally, there was a significant interaction effect for ENG and SRP on memory retention and retrieval of learned information. Students with ENG scored significantly higher with SRP than without SRP. Students with no ENG scored significantly higher with SRP than without SRP. Students with SRP scored significantly higher with ENG than without ENG. Students with no SRP scored significantly higher with ENG than without ENG.

The results from this study shed light on the inefficiencies of using a traditional lecture style while acquiring student self-assessment skills at the graduate healthcare level. In this study, students achieved significantly higher academic performance in retaining, retrieving and applying core course content using either active engagement or spaced retrieval practice compared to traditional lecture format. Additionally, students achieved significantly higher academic performance in retaining and retrieving core

course content using both active engagement and spaced retrieval practice together. The addition of engagement alone yielded a larger effect size than the addition of spaced retrieval practice alone. With the significant interaction on the multiple-choice examination, adding engagement alone yielded a stronger effect than adding spaced retrieval practice alone. However, adding both engagement and spaced retrieval practice improved mean scores significantly with a large effect size. Lastly, students reported significantly higher confidence level scores in retaining, retrieving and applying core course content using either active engagement or spaced retrieval practice. As a result of the positive outcomes associated with student engagement and spaced retrieval practice on learning self-assessment skills, further evaluations are needed on a wider range of dental students and learner topics.

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INTRODUCTION

Dental education is facing many curricular challenges to promote students'

professional competencies (Tucker, Efurd, & Kennedy, 2018). In particular, one of the

most challenging areas is promoting dental students' ability to identify gaps in their

knowledge and hand skills performance, particularly through self-assessment activities

(Tuncer, Arhun, Yamanel, Çelik, & Dayangac, 2015). Self-assessment is a self-directed

learning technique that places the student in control of their own learning process through

self-identifying strengths and modifying weaknesses. (Bohaty, Redford, & Gadbury-

Amyot, 2016). Students set the pace of their own learning in a low-stakes environment to

promote a deeper reflection and evaluation of their performance outcomes (Chamber &

LaBarre, 2014). A critical area of focus in dental school programs is developing and

implementing instructional techniques and learning environments that offer students the

opportunity to advance their knowledge and practice of self-assessment (Palatta et al.

2017). Therefore, structuring dental education (e.g., curriculum, instruction) should

advance key student performance outcomes (e.g., self-assessment, professional

competencies) to overcome these aforementioned challenges.

There are sixty-seven dental schools in the United States with six additional

dental schools opening in the last three years (American Dental Association [ADA],

2019). Of the sixty-seven dental schools, 95% are four-year post baccalaureate programs

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where peer-selection admissions admit students meeting selection criteria, and 93% of the schools have a two-year preclinical curriculum followed by a two-year clinical curriculum (ADA, 2019). In consideration of the new dental schools, the Commission on Dental Accreditation (CODA) has recommended the creation of a shared set of student performance outcomes for all accredited programs. As directed by CODA Standard 2-11, students 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. Additionally, CODA has called for the use of evidence-based instructional techniques within dental education to promote student engagement and student-centered learning. However, the process of self-assessment is a new concept to many beginning dental students who are predominantly high academic achievers and skillful at multiple-choice examinations (Tuncer et al., 2015). Consequently, many new dental students have not developed the cognitive skills associated with self-assessment and therefore must be taught (Curtis, Lind, Dellinges, Setia &Finzen, 2008). Self-assessment concepts must be presented in a way that helps students to develop cognitive skills through reflection, behavior modification, and incorporation during future experiences (Kraiger, Ford, & Salas, 1993).

Unfortunately, Palatta et al. (2017) report many dental institutions implement outdated curriculum and instructional techniques with an overabundance of material to deliver within a four-year program. Furthermore, within dental instruction, it is common to observe the use of passive, teacher-centered traditional instructional techniques (e.g., lectures) with limited student engagement (Axelson & Flick, 2011). An example of this passive, teacher-centered traditional instruction method would be a presentation style

where students sit and listen to course content over an extended period without engagement or interaction with course material (Michael, 2006). Passive instruction is the least effective instructional technique for engaging course content and creating student-centered learning (Azevedo, 2017). Instructional approaches that have shown to foster student-centered learning in the current literature immerse and engage students in the learning process through self-reflection, peer feedback and behavior modification (Huba & Freed, 2000). Consequently, passive instruction contradicts the current call from CODA to employ evidence-based instruction techniques while creating student-centered learning and life-long learners.

Student-centered instruction is an instructional technique that places the student in the center of his or her own learning (Huba & Freed, 2000). This is accomplished by allowing the student to have influence over content, formative activities, materials and pace of learning (Barr & Tagg, 1995). The instructor then provides opportunities for students to learn independently while guiding skill sets for promoting success (Collins & O'Brien, 2003). Instructional techniques that support student-centered learning in the current literature are active learning (Bonwell & Eison, 1991), collaborative learning (Brufree, 1984) and cooperative learning (Johnson, Johnson, & Smith, 1991). Student-centered instruction can then be viewed through the lens of the adult learning theory on how active engagement can promote key student outcomes in dental education. Student-centered learning is said to promote a deeper understanding of course materials and therefore elicits students' metacognitive abilities (Aleven, Roll, McLaren & Koedinger, 2010), self-regulation (Graesser & McNamara, 2010), and self-efficacy (Dunlap, 2005).

Students' ability to engage in effective self-assessment to improve professional practices is a key outcome of dental school programs (Chamber & LaBarre, 2014). Within dental programs, a low-stakes environment offers an environment where students can make mistakes, identify those mistakes and modify deficiencies without fear of failing grades (Madrazo, Lee, McConnell, & Khamisa, 2018). There are instructional techniques documented in the current literature that have shown to be beneficial in providing a richer learning environment that is engaging, student-centered and self-regulated (Carpenter, Cepeda, Rohrer, Kang & Pashler, 2012; Michael, 2006). One such instructional technique is engaged or active learning (Michael, 2016) where students are actively engaged in the course content as it is being delivered. According to Michael (2006), this environment embeds various learning activities within the instructional content for better application and understanding of core course content (e.g. think-pair, share, minute papers, practice problems, simulation). The learning activity of interest in this study is simulation to provide hands-on application of foundational course material used for self-assessment activities. Another instructional technique of interest is termed spaced retrieval practice whereby course content is broken over several sessions and students are asked to retrieve key tenants or take-away concepts (Carpenter, Cepeda, Rohrer, Kang, & Pashler, 2012). This environment is said to provoke retrieval of learned information at successive sessions to promote better retrieval for future applications (Cepeda et al., 2006; Mozer, Pashler, Cepeda, Lindsey, & Vul, 2009).

In the pursuit of CODA Standard 2-11, it has become necessary to explore engagement and spaced retrieval practice as alternative instructional techniques for students learning self-assessment skills. Dental education research has shown a

significant delay in dental student comprehension and clinical application of information needed to hone self-assessment skills using a passive, traditional instructional technique (Metz et al., 2017). Much of the research on engagement and spaced retrieval practice techniques focused at the K-12 level and undergraduate college level buts still needs to be evaluated at the graduate training level (Hopkins, Lyle, Hieb, & Ralston, 2016; Karpicke & Grimaldi, 2012; Roediger & Karpicke, 2006). However, the empirical data supports improvements in academic achievement through memory retention and retrieval that warrant further investigation with dental students' self-assessment hand skills activities (Hopkins et al., 2016; Karpicke & Grimaldi, 2012; Roediger & Karpicke, 2006)

The purpose of this study was to evaluate student engagement and spaced retrieval practices as instructional techniques to promote self-assessment learning activities within dental education. These instructional techniques were compared to the traditional instructional technique currently being used with D1 dental students. Data from this experimental study was used to bridge gaps in the current literature on how student engagement and spaced retrieval practice could help promote self-directed learning for self-assessment activities. Structuring dental education (e.g. curriculum, instruction) should advance key student performance outcomes (e.g. self-assessment, professional competencies). A deeper exploration into the theoretical frameworks used as a lens for structuring dental education and key student performance outcomes will follow.

Theoretical Framework

There are several relevant theoretical frameworks in the education literature that support and promote student self-assessment. The Cognitive and Constructivist Learning

Theories (Duffy & Jonassen, 2013; Piaget, 1968), the Metacognition Theory (Flavell, 1976; Schraw, 1998), and the Self-Efficacy Theory (Bandura, 1977; Bandura, 1997) all provide a lens on how student self-assessment can become a meaningful process in the correct environment while immersed in the core course content.

One instructional technique that promotes student-centered learning is called active or engaged learning (Bonwell & Eison, 1991). Active learning immerses and engages students in course content by allowing students to apply learned information through various activities (Michael, 2006). Students then become active participants in the learning process and not merely passive listeners (Morales, 2017). Active learning promotes self-regulation of learner objectives by allowing students to pace their own learning (Prince, 2004). Active learning has shown positive student outcomes in terms of memory retention and retrieval of learned information (Michael, 2006). Active learning gains support through the theoretical foundation of the adult learning theory proposed my Malcolm Knowles in 1978 (Knowles, 1978; Knowles, 1984). Knowles (1978) suggested that adults learn better when content is relevant, engaging and self-directed. Additionally, active learning gains theoretical support through the cognitive learning theory where experiences and activities create knowledge (Duffy & Jonassen, 2013; Piaget, 1968). As dental education looks to enhance structuring (e.g. curriculum, instruction), creating a student-centered learning environment should be at the forefront of planning by creating self-directed learners (Palatta, 2017). Self-directed learners will then self-evaluate, identify gaps in their knowledge/skills, modify knowledge/skills, assimilate new knowledge/skills and apply new knowledge/skills (Brookfield, 1985). Therefore, active learning requires further evaluation in dental education to obtain key student performance

outcomes like promoting self-assessment skills. Self-assessment is promoted within a student-centered learning environment while honing deeper cognitive skills like metacognition (Siegesmund, 2016), self-regulation (Siegesmund, 2017) and self-efficacy (Panadero, Jonsson, & Botella, 2017).

Another instructional technique that has shown to improve memory retention and retrieval of learned information is termed spaced retrieval practice (Karpicke & Roediger, 2007). Spaced retrieval practice is a learning technique that requires students to rehearse information to be learned at different spaced intervals of time (Karpicke & Roediger, 2010). It is theorized that memory retention can be expanded for longer periods of time thus allowing students to retrieval learned information for future applications. The time between intervals is termed the spacing gap and varies from minutes to weeks across various studies (Karpicke & Roediger, 2010). The spacing gap can be fixed or expanding depending on the intended learner outcomes. The time interval following the last learning session and testing of the material is called the test delay interval (Karpicke & Roediger, 2010). The ultimate goal of spaced retrieval practice is accurate retrieval of learned information over longer periods of time (Lyle & Crawford, 2011; Roediger & Karpicke, 2006). As dental education looks to enhance structuring (e.g., curriculum, instruction), creating a learning environment that enhances memory retention and retrieval of learned information is crucial (Palatta et al., 2017). Therefore, spaced retrieval practice requires further evaluation in dental education to obtain key student performance outcomes like promoting self-assessment skills. Self-assessment is promoted with better memory retention and retrieval of learned information while honing deeper cognitive skills like

metacognition (Logan, Castel, & Viehman, 2012), self-regulation (Gandomkar et al., 2016), and self-efficacy (Gist, Schwoerer, & Rosen, 1989).

Student self-assessment is a complex process that nests itself in several relevant theoretical frameworks within cognitive psychology (Kostons, Van Gog, & Paas, 2012). Cognitive psychology is the branch of psychology that examines internal mental processes, such as problem solving, critical thinking, memory retrieval and language development (Eva & Regehr, 2005). Three cognitive psychology theoretical frameworks provide a lens to examine ways instructional practices may be used to promote students' self-assessment practices. These three frameworks are the Cognitive and Constructivist Learning Theories (Duffy & Jonassen, 2013; Piaget, 1968), the Metacognition Theory (Flavell, 1976; Schraw, 1998) and the Self-Efficacy Theory (Bandura, 1977; Bandura, 1995; Bandura, 1997). Collectively, these theories provide a lens for viewing how dental education should be structured (e.g., curriculum, instruction) to advance key student performance outcomes (e.g., self-assessment, professional competencies). These theories together address intimately how students gain information, assimilate information, retain information, retrieval information, apply information and modify existing information. Furthermore, the theories provide the foundational support for preparing students for self-assessment activities. Each of these theories are a key link in the chain that develops student-centered learning. The instructional techniques (active learning, spaced retrieval practice) pave the foundation to enrich student learning while promoting an environment for deeper cognitive learning (Bonwell & Eison, 1991; Logan et al., 2012). Each one of these theoretical frameworks will be briefly described with key tenants for application to self-assessment in dental education.

Constructivism is a theory that suggests individuals construct their own understanding and knowledge of the world through experiencing things and reflecting on those experiences (Ackerman, 2003). In constructivism, learning is therefore an active, constructive process (Hand & Treaugust, 1994). Two key concepts that create the construction of new knowledge are assimilation and accommodation (Fosnot, 2005). According to Larochelle, Bedarz, and Garrison (1998), assimilation allows people to incorporate new experiences into old experiences by rethinking misunderstandings or gaps in their current understanding. Accommodation is reframing new experiences into existing mental capacities. Assimilation and accommodation are two key tenants in dental education used in self-assessment. Without one or both of these, dental students will struggle to correct deficiencies in their hand-skills outcome assessment. The cognitive learning theory suggests that people mentally process information they receive versus simply responding to environmental stimuli (Wadsworth, 1971). Therefore, cognitive learning is premised on the mental process by which learners acquire, process, retain and retrieval information (Piaget, 1964). One of the several elements from those mental processes is memory retention and retrieval (Powell & Kalina, 2009). Self-assessment is a truly reflective process in dentistry where students acquire knowledge through measurable parameters on hand skill activity outcomes. However, students should be placed in a constructive learning environment that allows them to pace their own assimilation and accommodation of knowledge content through self-directed learning. It is through many formative experiences that students begin to progress towards self-directed learning and professional competencies. Students that originally made

unrecognized mistakes should now recognize and reflect on those mistakes to avoid similar mistakes in the future.

The metacognitive theory is the process of thinking about ones thinking (Flavell, 1978). According to Israel (2015), metacognition is then a critical awareness of ones thinking and learning as well as oneself as a thinker and a learner. Metacognitive practices increase the learner's ability to transfer or adapt their learning to new or future tasks (Flavell, 1978). Therefore, metacognitive practices help learners to become aware of their strengths and weaknesses as learners and adapt accordingly (Ibabe & Jauregizar, 2010). Identifying gaps in knowledge/skills is crucial in dental education. Dental students that can identify gaps and adapt accordingly are heading on the correct path to professional competence. According to Ibabe and Jauregizar (2010), students are said to have adequate metacognitive abilities when they can recognize limits to their knowledge and seek ways to expand that knowledge. Knowing ones strength and weaknesses can allow students to actively evaluate learning strategies, available resources and readiness for tasks (Flavell, 1978). In terms of self-assessment, students that have the ability to demonstrate effective metacognitive ability will benefit greatly moving through hands on experiences towards professional competencies. The identification of knowledge gaps, seeking ways to fill those gaps and applying new knowledge will help produce practice-ready dentists and self-directed learners. On the other hand, students that lack metacognitive abilities to recognize weaknesses are blissfully unaware of their own incompetence (Dunning, 2011). For many students entering dental school, this will be the first time that they have had to critically evaluate their own work seeking gaps in their knowledge/skills. Serious consideration and time is needed to allow students to develop

the skills needed to self-assess. Therefore, consideration should be given to how information is provided to the students and the environment set for learning. A low-stakes environment where students are fully engaged with feedback has been shown in the literature to foster a positive metacognitive environment (Schlosser, Dunning, Johnson, & Kruger, 2013).

The self-efficacy theory refers to an individual's belief that they possess the capacity to perform behaviors that meet specific outcomes (Bandura, 1977). According to Bandura (1977), self-efficacy is then a level of confidence in one's ability to control one's motivation, behavior and social environment. These cognitive self-evaluations influence goals, energy reaching goals and behavioral performance (Bandura & Adams, 1977). Self-efficacy is then a function of time and experience working towards said goals (Taylor & Betz, 1983). For dental students learning for the first time to critically evaluate their hands skills, a low self-efficacy should be expected (Pajares & Kranzer, 1995). However, it is imperative that students are placed in a low stakes environment with feedback that allows them to become more confident in their abilities to self-assess (Pajares & Kranzer, 1995). According to Paulsen and Betz (2004), self-efficacy and confidence can work in a positive cycle. Meaning that the more confident a student is in their self-assessment abilities, the more likely they are to engage in self-assessment, which provides them with formative experiences needed to develop a positive self-efficacy.

Self-assessment, in summary, gains theoretical support through four distinct theories of learning. In referencing Figure 1, the four theoretical frameworks can be viewed as pillars supporting the overall learning process of performing self-assessment.

Figure 1.
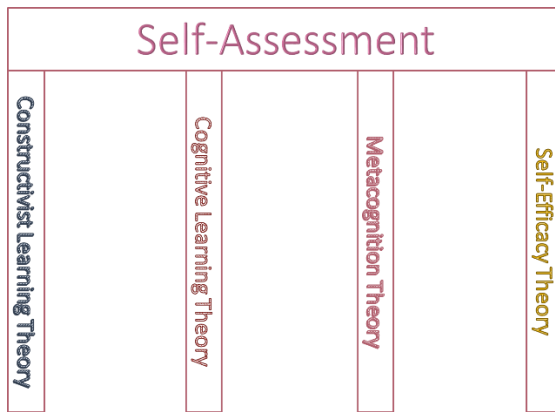
Theoretical Pillars Supporting Self-Assessment

Note. Each theoretical pillar represents a unique and supportive leg that in part enhance student self-assessment capabilities.

As shown in Figure 1, constructivism focuses on the idea that learning occurs after creating meaning through life experiences (Duffy & Bednar, 1991). Cognitive theories focus on students' learning processes and how information is obtained, assimilated, retained and retrieved by the mind (Sweller & Paas, 2017). Metacognition is what enables a student who has been taught a particular strategy in a particular problem context to retrieve and deploy that strategy in a similar but new context (Susser & McCabe, 2013). Self-efficacy is posited to influence individuals approach to learning, motivation, and subsequent performance, as people will often attempt to learn and perform only those tasks for which they believe they will be successful (Lisda & Harina, 2018). Each of these four theories, in part, will collaboratively enhance student learning and promote meaningful self-assessment activities towards clinical competence. That is, if students can create understanding of self-assessment through many formative

experiences, contextualize and retrieve information, modify behaviors through reflection and obtain a level of confidence needed to enhance the self-assessment process.

As new dental students are introduced to the construct of self-assessment, how information is provided is crucial to the development towards professional competencies. Therefore, the instructional technique and hands on learning environment by which grading criteria are introduced for self-assessment should be considered while seeking to optimize metacognitive skills and self-efficacy. For the purposes of this study, two factors (independent variables) will be looked at in terms of classroom instructional techniques: level of student engagement and use of spaced retrieval practice. In looking at level of engagement, students will either be passive listeners to a lecture presentation on grading criteria or engaged with hands on simulation throughout the lecture presentation. In looking at spaced retrieval practice, students will either have a single lecture presentation without a retrieval activity on grading criteria or two spaced lecture presentations with a spaced retrieval activity following each.

Problem Statement

As of today, the University of Louisville School of Dentistry (ULSD) is not meeting the mandates placed by CODA in using evidence-based instructional techniques to create student-centered learning in Standard 2-11. In spite of the calls from governing bodies, the ULSD still continues to use passive, non-engaging instructional techniques due to constraints in time, space and resources within the current curriculum. These constraints and faculty limitations results in students performing hurried self-evaluations without adequate peer feedback overlooking critical mistakes. Consequently, students

could be at risk of not understanding the value of self-assessment, student-centered learning and the tools to become life-long learners. Just as important, students may continue to struggle with self-assessment and delay progress towards clinical competencies. Dental student self-assessment of hands-on clinical procedures is the epitome of critical thinking and problem-solving skills needed to establish clinical competence (Quick, 2016). If as dental educators we can arm students with the ability to critically evaluate their own work, only then have we helped to create life-long learners (Mays & Branch-Mays, 2016).

The CODA (2019) mandates 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. To promote students' outcome attainment, dental schools must first interpret this standard, then implement successful assessment strategy goals and ultimately provide some qualitative or quantitative data to suggest attainment. For students to be able to accurately self-assess, dental institutions must provide adequate and relatable instructional techniques to expedite and improve expected learner outcomes. The literature suggests that placing students in a low-stakes, student-centered environment during instruction should promote memory retention, retrieval and application of learned concepts (Van Merrienboer, Croock & Jelsma, 1997). Additionally, both active learning and spaced retrieval practice instructional techniques have promoted and honed student metacognitive abilities, self-efficacy and student-centered learning (Ballen, Weiman, Salehi, Searle, & Zamudio, 2017; Diekelmann & Lampe, 2004; Susser & McCabe, 2013).

It has become apparent that the traditional instructional technique currently employed at ULSD has not awarded dental students the opportunity to obtain a deep understanding for the construct of self-assessment. Students continue to lack understanding of the conceptual knowledge, retention, retrieval and clinical application needed for self-assessment too far into their four-year curriculum (Metz et al., 2017). In other words, the time taken to achieve accurate self-assessment strategies occurs too late in the fourth year of dental education. Currently, there are no published studies in the professional healthcare education literature that have evaluated using spaced retrieval pratice and simulated active learning to improve students' self-assessment skills following a standardized grading rubric. Much of the research has been performed within undergraduate curricula and K-12 education with promising results (Hopkins, Lyle, Hieb, & Ralston, 2016; Roediger & Karpicke, 2006; Karpicke, Butler, & Roediger, 2009).

Purpose of the Study

The purpose of this study was to evaluate student engagement and spaced retrieval practice as potential instructional techniques in dental education to promote self-assessment learning activities. These instructional techniques were compared individually and collectively to the current traditional instructional technique currently being used with D1 dental students. Data from this experimental study was used to bridge gaps in the current literature on how active learning, spaced retrieval practice and these together could help promote self-directed learning for self-assessment activities. Structuring dental education (curriculum, instruction) should advance key student performance outcomes (self-assessment, professional competencies). Through the use of an engaged curriculum, it was hypothesized that students will enhance memory retention, retrieval and clinical

application of grading criteria used for self-assessment at the graduate healthcare level. Additionally, it was hypothesized that students will report a high self-efficacy when engaged in the core content while awarded spaced retrieval practice of learned information. The results from this study provided evidence-based outcomes to shape discussions at the ULSD in meeting CODA directives and establishing a new curricular model.

Significance

It is imperative that dental programs provide a learning environment that is student-centered and encourages self-regulated learning. If not, students will continue to make mistakes that could potential be harmful to patients without the ability to modify their outcomes. Implementation of these techniques require time in the curriculum that is currently not allowed due to many constraints, including time, space, and resources. Imai, Kresyman, and Asadoorian (2016) looked at the factors associated with implementing problem-based learning activities into a dental school curriculum and determined it was time consuming and resource heavy for implementation. However, its comparable to the constraints facing simulated engages learning and spaced instruction. They determined that student performance improved when time, space and resources were allocated, and the students were immersed in the course content. Hand-skills are the one aspect that students rarely get to prepare for prior to entering dental school resulting in potentially low self-efficacy and immature metacognitive abilities. Additionally, hand-skills performance are not part of the admissions process for any dental school in the United States. Therefore, the majority of students are truly novice at self-assessment activities resulting in overinflated or erroneous self-evaluations.

The current issue faced is that students are still learning their self-assessment skills while in patient care when they should be honing them (Metz at el., 2017). The delay in self-assessment skills is believed to be the current instructional technique and the lack of student development time in the current curriculum at ULSD. The first goal for this proposed study was to provide quantitative data to make evidence-based decisions for the future of dental education and the curriculum at ULSD. Additionally, the data from this study contributed to the overall knowledge in the literature on the effectiveness of active learning and spaced retrieval practice to promoting dental students' learning outcomes. Previously, there exists a gap in the literature on how spaced retrieval practice and simulated active learning could be used to improve retention, retrieval and application of grading criteria needed for self-assessment. The implications of this study were significant in terms of dental education, creating life-long learners and providing a curricular platform for other dental schools deficient in the area of student self-assessment. Additionally, a second goal provided a learning environment for students that promotes self-regulated learning while satisfying mandates from CODA. For this study, it was hypothesized that the utilization of engaging simulated activities and spaced retrieval practice instructional technique will improve students' conceptual knowledge, memory retention, retrieval, clinical application and self-efficacy of the grading criteria compared to the current model.

Research Question

Within this study, key independent variables of interest include students' level of classroom engagement and spaced retrieval practice. Each independent variable includes two levels. Specifically, engagement includes: no engagement and engagement of core

content material. Spaced retrieval practice included two levels: no spaced retrieval practice and spaced retrieval practice of learned information. Therefore, a 2x2 factorial design was used to evaluate significant main effects for each factor and any potential interaction between the independent variables. An experimental design has been developed to look at these instructional techniques for possible implementation at the ULSD. Both engaged simulation and spaced retrieval practice will be compared to the current passive, traditional instructional technique (control) being utilized on student knowledge and application of a standardized objective grading rubric used for self-assessment. The first dependent variable in this study will be student performance on memory retention and retrieval of grading criteria using a thirty-question multiple-choice examination. The second dependent variable in this study will be student performance on memory retention, retrieval and application of grading criteria using a hands-on simulated activity scored by students. The third dependent variable in this study will be a ten-question self-efficacy questionnaire gauging students' confidence in applying key tenants from the course grading rubric. The design of this research project was guided through gaps in the current literature, delays in student self-assessment skills and CODA reporting mandates. Accordingly, these problems/limitations led to the following research questions:

1. Does spaced retrieval practice and active learning (simulated) improve student's memory retention, retrieval and application of objective grading criteria used for self-assessment compared to a traditional lecture?

2. Does spaced retrieval practice and active learning (simulated) improve student's reported self-efficacy towards applying key grading criteria used for self-assessment compared to a traditional lecture?

Research Hypotheses

1) Engagement will be associated with increased information retention (test performance), hands-on simulated activity, and self-efficacy scale than D1 students within no engagement condition.

2) Spaced retrieval practice will be associated with increased information retention (test performance), hands-on simulated activity, and self-efficacy scale than D1 students within no spaced retrieval practice condition.

3) There will be an interaction effect of engagement and and spaced retrieval practice on information retention (test performance), hands-on simulated activity and reported self-efficacy scale among D1 students.

Null Hypotheses

1) There is no main effect for level of engagement on the multiple-choice examination, hands-on simulated activity or reported self-efficacy scale.

2) There is no main effect for use of spaced retrieval practice on the multiple-choice examination, hands-on simulated activity or reported self-efficacy scale.

3) There is no interaction of level of engagement and spaced retrieval practice on the multiple-choice examination, hands-on simulated activity or reported self-efficacy scale.

Definitions

Traditional Instruction: A teacher-centered approach to teaching in which students are audience participants sitting through presentations passively with little to no engagement or professional interaction (Bohaty, Redford, & Gadbury-Amyot, 2016).

Engaged/Active Instruction- A student-centered approach to learning in which students engage the material they study through reading, writing, talking, listening, performing and reflecting (Bohaty, Redford, & Gadbury-Amyot, 2016).

Simulated Active Learning- Simulated active learning-based healthcare education is defined as any educational activity that utilizes simulation aides to replicate clinical scenarios (Meyers, Jones, & Jones, 1993).

Spaced Instruction-Spaced instruction is an educational method that spaces instruction content over more than one exposure. (Toppino & Gerbier, 2014).

Retrieval Practice Effect- a phenomenon whereas practice in retrieving information enhances long-term retention of information better than restudying material (Rowland, 2014)

Spacing Effect- a phenomenon whereas increasing the temporal interval between learning activities leads to enhanced retention of information (Cepeda et al., 2006)

Spaced Retrieval Practice- Once a student grasps information enough to retrieve it, additional retrieval of that information will increase the likelihood of long-term retention (Karpicke, 2009; Karpicke & Reodiger, 2008) and increasing interval exposures between

retrieval opportunities increases the overall impact of retaining information (Hopkins, Lyle, Hieb & Ralson, 2015; Karpicke & Roediger, 2007; Pyc & Rawson, 2007).

Metacognition- Metacognition, generally defined as thinking about one's thinking, has been linked and compared in the past with a variety of terms: consciousness, self-reflection, self-awareness, language, frontal lobe function, agency, and theory of mind. (Medina, Castleberry, & Persky, 2017).

Self-Assessment- Self-assessment has been defined in the current literature as an assessment or evaluation of oneself or one's actions and attitudes, in particular, of one's performance at a job or learning task considered in relation to an objective standard or rubric. (McMahan, Pinckard, Jones, & Hendricson, 2014).

Self-regulated Learning-Self-regulated learning is a cyclical process, wherein the student plans for a task, monitors their performance, and then reflects on the outcome. (Susser & McCabe, 2013).

Summary

The information gained from this research project was key in challenging the current curricular model used for hand-skills courses at ULSD. As ULSD strives to improve its curriculum during this extensive review process, this study yielded empirical evidence that can be utilized for critical decisions that aim to meet CODA directives and student performance outcomes. Additionally, the empirical evidence from this study filled gaps in the literature on spaced instruction and active learning. Previously, there was a gap in the education literature on using active learning in combination with spaced retrieval practice in the professional school environment. Lastly, the empirical evidence

helped create the optimal learning environment for students to learn about self-

assessment and its relationship to clinical competence and life-long learning.

CHAPTER 2

REVIEW OF LITERATURE

Dental education is unique in healthcare education in that it teaches students hand-skills techniques required for clinical competency in restorative dentistry starting upon program entry (Lukas, Hardy, Johnson & Brownstein, 2019). This requires students to be exposed to the hand-skills assessment criteria in a way that promotes a deeper understanding, retention, and retrieval of information gathered through their preclinical curriculum for clinical pratice (Chambers & LaBarre, 2014). Currently, many dental institutions still deploy a curriculum that lacks significant engagement and retrieval opportunities of the core course content lending itself to limited understanding, retention and retrieval of learned information (Michael, 2006). Therefore, dental curricula must provide knowledge acquisition through instructional methods that promote and enhance formative feedback through self-reflective exercises. Dental education requires that students incorporate, retain and retrieval information learned as novice professionals while learning to hone their self-assessment capabilities.

According to Jackson and Murff (2011), a crucial foundational concept is that students possess the ability to self-assess their own hand skills performance. Self-assessment capabilities are considered a formative process in the literature as the gold standard for achievement of self-directed learning (Chambers & LaBarre, 2014) and is the true epitome of progression towards achieving professional competency (Jackson &

Murff, 2011; Kostons, van Gog & Paas, 2012). In the pursuit of creating life-long learners, dental education institutions must reevaluate and be mindful of curricular design (e.g. instructional techniques, learning environment) needed to prepare students for self-assessment activities.

Outcomes in the literature suggest that students not only have the tendency to overlook errors in their own hand skills performance (Metz et al., 2017), but are delayed in understanding crucial concepts for self-assessment. Additionally, students that lack the ability to provide accurate self-assessments have the tendency to overestimate their academic performance (Redwood, Winning & Townswnd, 2010). This is coined the Dunning-Kruger Effect in which students reach erroneous conclusions and make unfortunate choices about their hand-skills. The Dunning-Kruger Effect is theorized to be brought on by a poor curricular environment through limited engagement of the core course material, a teacher centered learning environment and high stakes outcomes (Kruger & Dunning, 1999). Consequently, students may not acquire the metacognitive ability to self-assess and, correspondingly, obtain a false sense of self-efficacy (Kruger & Dunning, 1999). The purpose of this study is to investigate instructional techniques proven beneficial in the current literature not yet evaluated in dental education on preparing students for self-assessment activities. Structuring dental education (e.g. curriculum, instruction) should foster and promote key educational outcomes (e.g. self-assessment, professional competencies) following evidence-based literature.

Self-assessment is a formative self-reflective activity in which a student controls their learning through objective criteria (Satheesh, Brockmann, Liu, & Gadbury-Amyot, 2015). Designated objectives are typically assessed using a rubric in which an informant

(e.g., student, instructor) provides an evaluative judgement on an individual's

performance on some task. In dental education, a rubric can be used by students to

conduct a self-assessment of their hand skills performance (Kilgour, 2014). Through self-

assessment, it is hoped that students take control of their own learning through

identification of gaps or errors in their knowledge. The term coined for this learning

concept is self-regulated learning. In other words, it's a cyclic process where students

plan for an assigned task, monitor their own process and then reflect on the outcome

(Kostons, van Gog, & Paas, 2012). Professional programs have used self-assessment

activities for many years to promote and enhance student-centered learning (Jackson &

Murff, 2011; Kostons, van Gog, & Paas, 2012). Many dental institutions have developed

and incorporated the use of self-assessment grade sheets with some type of corresponding

grading rubric (O'Donnell, Oakley, Haney, O'Niell, & Taylor, 2011). However, there are

gaps in the current literature on how students learning self-assessment activities should be

engaged and information retrieved through curriculum and assessment.

For these reasons, this experimental study was designed to access student's

memory retention, retrieval and application of the grading rubric criteria for accurate self-

assessments using various instructional techniques during knowledge acquisition.

Additionally, sought will be student self-reported confidence levels on performing self-

assessment of key tenants located within the grading rubric (self-efficacy). One such

instructional method is nested in a theoretical concept called spaced retrieval practice

from the field of cognitive psychology (Bahrick, 1979; Carpenter et al., 2012; Bjork,

Dunlosky, & Kornell, 2013; Karpicke & Roediger, 2010; Karpicke & Grimaldi, 2012).

Spaced retrieval practice is premised in the notion that repeated exposure of information

spaced over time with retrieval opportunities will improve retention, retrieval and

application of that information (Hopkins, Lyle, Hieb & Ralson, 2015; Karpicke, 2009;

Karpicke & Roediger, 2007; Karpicke & Reodiger, 2008). Spaced retrieval practice

among adult learners seeks to promote better retention, retrieval and practical application

of learned material. For D1 dental students entering dental education, the use of spaced

retrieval pratice could allow students time to perform essential experiences on the path to

professional competency. In spacing the core content with retrieval opportunities, student

could develop stronger skill sets at a pace that promotes self-regulated learning. In this

study, spaced retrieval practice in combination with active learning is hypothesized to

improve memory retention, retrieval and application of self-assessment criteria when

compared to a passive traditional instructional method. Additionally, the combination of

active learning and spaced retrieval practice is believed to illicit more confident students,

which in turns yields higher self-efficacy towards performing self-assessment.

Another instructional method is nested within the conceptual foundation of active

leaning or engagement through student directed learning performing simulated activities

(Michael, 2006; Prince, 2004). Through the lens of the *adult learning theory* (Knowles,

1984), the incorporation of simulated activities places the learning directly into the

learner's hands to make it relevant and active (Lin & Song, 2017). If spaced retrieval

practice and active learning are beneficial to improving retention and retrieval of

information, then self-assessment capabilities should improve. When self-assessment

becomes a true reflective process through retrieving information, student learning will

become self-regulated and students should enhance their metacognitive skills and feelings

of positive self-efficacy (Kostons et al., 2012). The goal of becoming self-regulated

learners while in dental training is to promote professional competency, prepare student

for graduation and encourage lifelong learning in practice (Nilson, 2013). Self-regulated

in that fact that as dental students can begin to identify gaps in the hands-skill

performance outcomes and as practitioners identify critical errors that could potentially

compromise clinical outcomes (Roeser & Peck, 2009).

Within dental education, several external factors influence curricular activity and

shape dental initiatives (Roeser & Peck, 2009). Among others, these include higher

education directives, institutional competency statements, and curricular innovation

(Palatta et al., 2017). The progression of students towards competence is mandated

through governing agencies to find new and innovation ways to implement pedagogy.

Palatta et al. (2017) has defined new and innovative pedagogy as creating a formative

student-centered learning environment where students can control their learning. Palatta

et al. (2017) recommended using several pedagogies to engage students that included

self-reflection, patient simulation and peer-feedback. The commission on dental

accreditation (CODA) guides all accredited dental institutions to their expectations of

graduating dental professionals. CODA publishes standards of which dental institutions

must follow by developing specific competency assessments to meet said criteria

(Appendix C). From theses CODA standards, dental institutions formulate competency

statements that attempt to measure or assess student progress towards competence

(Appendix D). One such standard is that students must possess the ability to self-assess

their own work and identify critical errors that may be detrimental to their patient's

overall health (CODA Statement, 2-11). These assessments can come in the form of

written examinations, oral examinations, simulated hand skills examination and/or

patient-based hand skills examinations. The subjective assessments must use a grading

rubric to guide learners and evaluators to a profound learning experience through self-

reflection and critical thinking. Curricular change and innovation are key to the success in

the pursuit of CODA standards and competency statements in dental education.

Therefore, dental education must avail itself to the need of evidence-based curriculum

that promote student-centered learning towards professional competencies.

According to Palatta et al. (2017), many dental institutions are doing extensive

reviews of their curriculum in hopes to provide students with a student-centered learning

environment. The reviews are termed vertical reviews that seek redundancies of material,

gaps in concepts and evidenced-based pedagogy to foster student-centered learning. This

in turn can promote self-regulated learning on the path to professional competencies.

Dental institutions must be progressive and adapt to ever changing technologies to

improve students learning. Additionally, students must be provided the time with the

curriculum to develop the skills for accurate self-reflective activities. For these reasons,

this experimental study was designed to seek evidence-based data using various

instructional techniques to promote self-assessment skills, student-centered learning and

self-efficacy.

There exists a gap in the current literature into how spaced retrieval practice and

active learning (simulation) together could benefit students in retaining, retrieving and

applying crucial information for self-assessment activities (Hopkins, Lyle, Hieb, &

Ralston, 2016; Karpicke & Roediger, 2007). Reported in the current literature, the use of

a passive traditional lecture for self-assessment skills development is not creating a

student-centered learning environment (Metz et al., 2017). Therefore, this experimental

study was designed to investigate the degree to which spaced retrieval practice and active learning (simulation) could improve dental students' retrieval of criteria required for self-assessment and their self-efficacy doing so, compared to a traditional instruction approach. Acquired information will help to address the literature gap regarding strategies to improve dental students' memory retention, retrieval and clinical application of self-assessment criteria. The ultimate goal of this study is to yield empirical evidence to guide decision related to the placement of dental students into a learner-centered learning environment supported by engaging and retrieval-based curricula. Study implications relate to decision-making related to curriculum, instruction, and assessment. Empirical results will also provide direction for future research, such as creating and implementing student-centered learning environments across healthcare education.

The subsequent literature review is designed to examine external factors and governing bodies that influence and shape dental education on the path to student professional competencies. The theoretical frameworks and supporting literature associated with self-assessment and their association with cognitive psychology will be reviewed and discussed. Specifically, the Cognitive and Constructivist Learning and Motivation Theories, the Metacognition Theory and Self-efficacy Theory. Additionally, the theoretical frameworks for knowledge acquisition using various instructional techniques will be evaluated for application to adult learning in the attainment of professional competencies. The aim of presenting this literature review is for the reader to understand that self-assessment requires a deeper level of cognitive skills using instructional techniques that foster student-centered learning.

Factors Influencing Dental Education

There are several external factors influence and shape dental education that invariably influence students' development of professional competencies (CODA, 2019; Palatta et al., 2017). Governing entities and accrediting bodies are two external factors that influence dental education outcomes across institutions and programs alike. This section identifies these two key external factors influencing dental education and demonstrates the way in which they may promote or hinder students' development of professional competencies.

The United States Department of Education Commission on the Future of Higher Education (2006) identifies the key objectives for American higher education. In part, these objectives call for the utilization of high-quality instructional strategies, creation of new knowledge, incorporation of technology, and the acquisition of practical workplace skills. Education institutions that provide higher learning are recommended by accrediting bodies to demonstrate their ability to provide students with a high-quality education (Pascarella, Seifert, & Blaich, 2010). Pascarella, Seifert, and Blaich (2010) posited that the aforementioned initiatives demand that educational institutions continually change and adapt the ways in which teaching and learning are carried out in our higher education institutions. Axelson and Flick (2011) suggested that faculty must be willing to explore approaches beyond traditional methods to broaden educational experiences for a more diverse group of students. Additionally, students and instructors must share the responsibility for the quality of their learning experiences (Axelson & Flick, 2011; Pascarella et al., 2010). Although students must actively participate in the acquisition of knowledge and skills, instructors must continually strive to provide an environment that promotes student learning (Axelson & Flick, 2011).

The most influential governing entity in dental education is the CODA, which serves the public and dental profession by developing and implementing accreditation standards that promote and monitor the continuous quality and improvement of dental education programs. The CODA was established in 1975 and is nationally recognized by the United States Department of Education (USDE) as the sole agency to accredit dental and dental-related education programs conducted at the post-secondary level. Every seven years dental institutions must complete a comprehensive self-analysis and self-study report detailing its resources, curriculum, policies and operational standards. The self-study is followed by an on-site team review by a team of experts who conduct interviews of administrators, faculty, students and staff to ensure minimal standards are met. The standards set forth by the commission strongly influence curricular design and how dental institutions assess student progress. CODA's governance on dental education has a direct effect on how dental schools establish and monitor curricular design through competency statements for measuring student performance outcomes.

As dental education moves into the future, these external factors will become more influential to meet the demands that promote positive changes. There are gaps in the current literature on how instructional techniques may benefit student dental education when compared to a traditional model for developing self-assessment skills. The evaluation of educational techniques, like spaced retrieval practice and active learning, could lead to major curricular changes needed to meet CODA standards, ULSD competency statements and the attainment of professional student competencies. As we evaluate new ways to improve student progression towards professional competency, governing agencies needs to be mindful of the impact this may have on current curricular

models deployed across dental institutions. New instructional techniques require additional resources (e.g. time, money, planning) and learning environments (e.g. student centered) that will need careful planning.

Curricular Innovation

Dental education, not unlike other healthcare institutions, is resistant to change (Palatta et al., 2017). A recent meeting of the American Dental Education Association Commission on Change and Innovation (CCI) discussed the term curricular optimization (Palatta et al., 2017). Curricular optimization refers to data supported changes in curricula that enhance student learning while optimizing time allotments (Palatta et al., 2017). According to Sellami, Shaked, Laski, Eagan and Sanders (2017), incorporating writing, technology, and problem-solving activities in curriculum could encourage students to be active participants in their learning. Ballen, Wieman, Salehi, Searle, and Zamudio (2017) suggested that institutional practices that lead to high levels of student engagement are ones that include self-reflection, critical thinking, student-faculty contact, active learning, and prompt feedback. These recommended educational practices facilitate student learning and educators should incorporate them as a means to optimize student learning and preparing them for the workforce (Quick, 2016; Quinn, Smith, Kalmer & Burgoon, 2017). The calls in the current literature for curricular optimization need empirical validation prior to implementation in dental education. The calls in the literature are on the forefront of many reported recommendations provided too dental institutions by CODA during site visits. These recommendations are made to any dental program not meeting the intended outcomes located with the shared set of standards. Unfortunately, the recommendations made by CODA to any one school are not part of any public record

to date for other dental institutions to review. However, during the ULSD CODA site visit in 2015, a recommendation was given for not meeting standard 2-11 intended purposes. For that, ULSD has a yearly reporting requirement to address plans and implementation of protocols to rectify the deficiency in our current curriculum. Therefore, ULSD has a significant interest in optimizing the process of self-assessment through evidence-based pedagogy while obtaining clear outcomes for the upcoming 2022 CODA site-visit.

Theoretical Framework

In looking at potential instructional techniques for dental education, student knowledge acquisition, retention, retrieval and application of information should be evaluated. How students are immersed and engaged in core course content should be at the forefront of learning objectives and outcome measures. There are two theoretical frameworks in the current literature that have been the foundation of educational research in terms of knowledge acquisition, retention and retrieval of learned information. These are the adult learning theory and spaced retrieval practice. The adult learning theory is premised in the notion that adult learners learn best when content is relevant, engaging and applicable (Knowles, 1978). Spaced retrieval practice is premised in the notion that repeated exposures and retrieval opportunities of core course information improves memory retention, retrieval and application of learned materials (Hopkins, Lyle, Hieb & Ralson, 2015; Karpicke, 2009; Karpicke & Reodiger, 2008). Both of these learning theories possess key tenants in how information is presented to students in creating an environment that fosters deeper understanding of core course material. Some skill sets unique to dental education, like self-assessment, require a deeper cognitive approach

where students evaluate their own performance outcomes. In looking to advance a specific key student outcome, self-assessment is a complex process that nests itself in several relevant theoretical frameworks within cognitive psychology (Kostons, Van Gog, & Paas, 2012).

Therefore, these theoretical frameworks deserve consideration when evaluating key academic outcomes associated with self-assessment skills. There are four specific theoretical frameworks in cognitive psychology relevant to students' practices of self-assessment fostered by how core knowledge is presented, retained, retrieved and applied in practice. These frameworks are the Cognitive and Constructivist Learning Theories (Duffy & Jonassen, 2013; Piaget, 1968), the Metacognition Theory (Flavell, 1976; Schraw, 1998) and the Self-Efficacy Theory (Bandura, 1977; Bandura, 1997). Collectively, each of these theoretical perspectives offers a lens by which to examine how dental education can be structured (e.g. curriculum, instruction) to advance key student learning outcomes (e.g., knowledge, self-assessment). This sub-section identifies and describes each theoretical framework in terms of relevance to dental education.

Student Engagement (Active Learning) and Self-Directed Learning

Structuring dental education to advance key student performance outcomes should be at the forefront of curricular design and instruction. Engagement of adult learners and igniting self-directed learning has roots back to the adult learning theory proposed by Knowles (1978). Knowles (1978) suggested that adult self-directed learning comes from individuals that take the initiative to diagnose their learning needs, formulate learning goals, identify resources for learning, implement appropriate learning strategies

and evaluate learner outcomes. As novice dental students begin to hone skills in self-assessment, it is important to create a learning environment that is student-centered promoting self-directed learning (Bransford, 2000). In dental education this is important because new students have no previous formative dental knowledge for which to base effective decision making and/or behavior modifications. Therefore, students must be immersed in core content materials through many formative experiences in a low-stakes, student-centered learning environment. The adult learning theory will provide a lens to view dental education in a new light while seeking avenues to modify instruction for key student outcomes. First, it is necessary to discuss the problems associated with a current passive instructional technique currently deployed by many dental institutions.

The use of a passive, non-engaging instructional technique is still commonly used in all types of higher education. The literature coins this type of instruction technique a traditional model which is teacher centered (Bohaty et al., 2016). Non-engaged instruction, commonly coined traditional lecture, is a passive learning process encountered by students (Kalmakis, Cunningham, Lamoureux, & Ahmed, 2010; Bohaty et al., 2016). In this approach, students are not engaged in the learning experience and it is said to be a teacher-centered process (Morales, 2017; Sera & Wheeler, 2017; Tang & Chen, 2017). A passive lecture occurs when a facilitator reads or references a screen, typically from PowerPoint slides, and does not engage the audience (Arias, Scott, Peters, McClain, & Gluskin, 2016).   However, many dental institutions continue to deliver foundational knowledge in this instructional technique because of constrictions in time and course content (Tang & Chen, 2017). The implications of such instructional techniques on self-assessment can be detrimental to creating self-directed learning and

developing life-long learners. A traditional instructional technique does not allow students the time to pace their own learning and to develop the skills needed for self-assessment (Morales, 2017; Sera & Wheeler, 2017; Tang & Chen, 2017). Additionally, a traditional instructional technique does not create a low stakes environment as the students are basically learning the hand skills development on their own at the pace set by the course schedule. For these reasons, an instructional method that immerses and actively engages students' needs further evaluation in dental education.

Historically, the adult learning theory was founded on the principles that effective instruction is relevant, engaging, active and learner-centered (Knowles, 1984). Knowles (1984) made five assumptions about the characteristics of adult learners that could have a direct impact on structuring dental education curriculum and instruction. First the assumption of self-concept assumes as a person matures, self-concept moves from one of being a dependent learner toward one of being a self-directed learner. Second, the assumption of adult learner experience assumes as a person matures, they accumulate a growing database of experience that becomes an increasing resource for learning. Third, readiness to learn assumes as a person matures, readiness to learn becomes oriented increasingly to their professional developmental goals. Fourth, is the assumption of orientation to learning assumes as a person matures, time perspective changes from one of postponed application of knowledge to immediate application. Meaning, orientation toward learning shifts from one of subject-centered to one of problem-solving centered. Fifth, is the assumption of motivation to learn assumes as a person matures the motivation to learn is driven internally and less influences by external factors. Through

the lens of the adult learning theory, many researchers have evaluated the impact of adult student engagement in healthcare education.

Current research has coined the term active learning to imply student engagement where learners are immersed and engaged in core course material. The active learning classroom is then one that de-emphasizes traditional lecture and other teacher-centered forms of instruction in favor of engaged class environments that are learner-centered (Michael, 2006; Persky et al., 2017). Active learning is an approach to instruction in which students engage the material they study through reading, writing, talking, listening, performing, and reflecting (Bohaty, Redford, & Gadbury-Amyot, 2016). Active learning involves more than merely sitting in a classroom, listening, and taking notes (Michael, 2006; Persky et al., 2017). Morales (2017) identified the two essential elements of using active learning in the classroom: introducing student activity into the traditional lecture and the promotion of student engagement. It is crucial in active learning that students participate in the learning process through engaging tasks such as writing, reading, reflecting, thinking, and talking (Bohaty et al., 2016). In active learning, emphasis is placed on developing lifelong skills rather than the transmission and memorization of information (Sera & Wheeler, 2017). In dental education, a crucial performance outcome is developing students to become life-long learners that can identify poor outcomes and modify behaviors. Therefore, the use of active learning to educate novice student to the skill sets needed for self-assessment warrants further evaluation. Active learning encompasses many different instructional techniques available in the current literature.

Active learning strategies are a means to increase attention and interactive learning in the classroom (Arias et al., 2016). Formats and techniques that encourage

active learning are more centered on students, thus promoting student involvement, facilitating self-direction, and fostering critical thinking, problem-solving skills, and deep learning (Morales, 2017; Sera & Wheeler, 2017). Formats may include discussion, group work, video modules, case studies, concept analysis, concept mapping and/or simulation (Arias et al., 2016; Morales, 2017; Sera & Wheeler, 2017). The participation of the learner in higher order thinking tasks, such as analysis, synthesis, and evaluation, will facilitate the development of skills and knowledge acquisition and application (Pettit, McCoy, & Kinney, 2017). It has been reported that active learning can be used with all levels of learners (Arias et al., 2016; Morales, 2017; Sera & Wheeler, 2017). In threading back to the adult learning theory, adults learn best by being engaged and accountable through feedback mechanisms meaningful to their career goals (Arias et al., 2016; Morales, 2017; Sera & Wheeler, 2017).

The current literature reports an increase in short-term and long-term memory retention and retrieval of learned information on scholastic academic achievement examinations (Bommer et al., 2017; Lin & Song, 2017). The National Survey of Student Engagement (NSSE) has examined the engagement experiences of hundreds of thousands of students from over 1600 colleges and universities since 2000. The consistent results of these data show that hands-on, integrative, and collaborative active learning experiences lead to high levels of student achievement and personal development (Kuh, O'Donnell, and Schneider, 2017). A recent meta-analysis of 225 studies in STEM areas determines students achieve higher scores using active learning compared to traditional lecture (Freeman et al., 2014). Additionally, the literature reports a positive student perception in terms of readiness to see patients, comfortability applying core course content and

reducing stress (Bommer et al., 2017; Lin & Song, 2017; Nilsson, Clementsen & Konge, 2017). Active learning can positively affect student motivation (Owens, Sadler, Barlow, & Smith-Walters, 2017); in turn, the overall impact of motivation moderates key learning characteristics such as attention, memory consolidation and self-efficacy (Ballen et al., 2017). Although active learning encompasses many techniques (Samuelson, Divaris, & De Kok, 2017), active learning with simulation deserves further evaluation in dental education to avail possible benefits in obtaining key educational outcomes (e.g., self-assessment, professional competencies).

Lin and Song (2017) define active learning simulation as an artificial representation of a complex real-world process with sufficient fidelity with the aim to facilitate learning through immersion, reflection, feedback, and practice, minus the risks inherent in a similar real-life experience. Simulation in medical education mimics many of the physical features of an actual patient students are expected to encounter (Bommer et al., 2017; Lin & Song, 2017). Simulation activities attempt to replicate real-life situations as closely as possible by using scripted live patients, simulated fake patients, programmable software, and simulated equipment (Medley & Horne, 2005). Simulation provides students opportunities for critical thinking, prioritizes patient care, and includes no risk to live patients (Partin, Payne, & Slemmons, 2011; Thompson & Bonnel, 2008). Simulated activities promote knowledge retention (Horan, 2009; Partin et al., 2011; Thompson & Bonnel, 2008), theory into clinical practice (Thompson & Bonnel, 2008), problem-solving skills (Hawkins, Todd, & Manz, 2008), collaborative teamwork (Medley & Horne, 2005; Partin et al., 2011), and broader learning preferences (Comer, 2005). Simulation provides students the opportunity to develop and build their clinical skills in a

positive, controlled, and risk-free learning environment (Hawkins et al., 2008; Henneman & Cunningham, 2005; Horan, 2009; Partin et al., 2011; Thompson & Bonnel, 2008). Incorporating simulation in learning experiences has been shown to better prepare students for the nuances of complex patient care (Horan, 2009; Medley & Horne, 2005; Partin et al., 2011). In dental education, simulated active learning could be beneficial as an instructional technique to promote key performance outcomes as students move towards professional competencies.

Empirical data in current literature suggests positive student performance outcomes associated with simulated active learning and therefore warrants further discussion. For example, a survey by Bommer et al. (2017) found that medical students who performed emergency treatment on simulated patients perceived a much higher readiness for emergency patient care than did student who did not perform simulated treatment. Patient simulation has been used to assess student competence for several years, evaluating critical-thinking skills, problem-solving skills, and clinical aptitude (Nilsson, Naur, Clementsen, & Konge, 2017). Nilsson et al. (2017) found that medical students exposed to simulation exercises performed higher on unit and oral examinations compared to students who were not exposed. Simulator training provides medical students with opportunities to practice procedures and make errors without causing harm to a real patient (Bommer et al., 2017; Lin & Song, 2017; Nilsson et al., 2017).

Lin and Song (2017) reported that medical students had higher critical thinking skills when altering patient medications on the simulator compared to students not using the simulator. Simulation has been shown in the current literature to reduce anxiety in medical students while promoting confidence in reasoning and eliciting critical-thinking

skills (Bommer et al., 2017). Bommer et al. (2017) suggested that medical residents perceived less anxiety while engaging critical thinking skills on the simulator versus during actual patient care for complicated cardiopulmonary resuscitation. Using active learning simulation in a low-stakes learning environment allows students to assimilate learned information, retrieval learned information, apply learned information and modify information in different contexts (Comer, 2005; Hawkins, Todd, & Manz, 2008; Henneman & Cunningham, 2005; Horan, 2009; Medley & Horne, 2005; Partin, Payne, & Slemmons, 2011; Thompson & Bonnel, 2008). According to this empirical data, active learning simulation warrants further evaluation while structuring dental education to promote key performance outcomes (e.g. self-assessment, professional competencies).

Spaced Retrieval Practice

Spaced retrieval practice resulted from the combination of two well-known phenomenon, the retrieval practice effect and the spacing effect (Hopkins, Lyle, Hieb & Ralson, 2015). The retrieval practice effect posits that practice in retrieving information enhances long-term retention of information better than restudying material (Rowland, 2014). The spacing effect posits that increasing the temporal interval between learning activities leads to enhanced retention of information (Bahrick, 1979; Carpenter et al., 2012; Cepeda et al., 2006; Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013; Karpicke & Roediger, 2010; Karpicke & Grimaldi, 2012). Spaced retrieval practice is then the combinations of the retrieval practice effect and the spacing effect (Hopkins, Lyle, Hieb & Ralson, 2015).

The retrieval practice effect has shown to increase student academic performance in the classroom through retrieving learned information (Goosens et al., 2014; Lyle & Crawford, 2011; McDaniel et al., 2013; McDermott et al., 2014; Rowland, 2014). The spacing effect has also shown to enhance retention of learned information in the classroom (Carpenter et al., 2009; Cepeda et al., 2006; Kupper & Tetzel., 2014; Sobel et al., 2011). Therefore, the spaced retrieval practice posits that once a student grasps information enough to retrieve it, additional retrieval of that information will increase the likelihood of long-term retention (Karpicke, 2009; Karpicke & Reodiger, 2008). In addition, increasing interval exposures between retrieval opportunities increases the overall impact of retaining information (Hopkins, Lyle, Hieb & Ralson, 2015; Karpicke & Roediger, 2007).

In a meta-analysis conducted by Cepeda et al. (2006), participants who used spaced practice on memory tasks achieved higher academic scores than those using massed traditional practices. In another study, Sobel, Cepeda and Kapler (2011) required 39 middle-school children study eight new English words during two sessions with a 1-week break between study sessions. The children learned the words under two different learning conditions (massed vs. spaced). In the massed condition, the two study sessions took place in immediate succession in session one. In the spaced condition, however, the two learning sessions were separated by a 1-week break in between study sessions. Thirty-five days after the second learning session, a cued retrieval test assessed children's performance. The results revealed that the retrieval for spaced items was significantly better than the retrieval for massed items. Bird (2010) found that the learning of English grammatical rules in adult students, as assessed by a test given 2 months after learning,

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was enhanced by practicing these rules with a 14-day spacing gap as compared to a three-day spacing gap. In another study, Kapler, Weston, and Wiseheart (2015) found that college students attended a 45-min lecture on meteorology and then reviewed the information (in a quiz with corrective feedback) either 1 or 8 days later. On a final test 35 days after the review session, students in the 8-day condition performed better than those in the 1-day condition not just on the factual retrieval questions but also on the questions that required application of knowledge. Other studies support spaced practice of mathematics problems (Rohrer & Taylor, 2006) and ecology lessons (Gluckman, Vlach, & Sandhofer, 2014). Karpicke and Roediger (2010) explored the concept of expanded spaced retrieval to see if students could retain information long-term compared to using equal spaced retrieval.

There is a lack of consensus in the current literature on spacing effect time (Carpenter et al., 2012; Cepeda et al., 2009; Dempster, 1988; Dunlosky et al., 2013; Küpper-Tetzel et al., 2014). Studies in the literature have evaluated the manipulation of repeated exposure times to learner concepts and measured student memory retrieval (Carpenter et al., 2012; Cepeda at el., 2008; Karpicke & Grimaldi, 2012; Karpicke & Roediger, 2010). One common finding from the body of research is learning is better when two or more exposures to concepts are separated, regardless of time. In looking at spacing gap, students retained a greater number of vocabulary definitions when a given term and definition were repeated approximately every 5 minutes, rather than when the same term and definition were repeated consecutively (Dempster, 1988). The duration of spaced exposures varies across the current literature from a few seconds to several weeks (Carpenter et al., 2012; Cepeda et al., 2008; Cepeda et al., 2006; Kornell, Castel, Eich, &

Bjork, 2010; Karpicke & Roediger, 2010; Karpicke & Grimaldi, 2012). There seems to be a lack of census in the current literature that supports specific spacing gap times.

There is no evidence in the current literature that supports the use of any one spacing gap time or any literature that has compared spacing gap time. However, it has been reported that longer spacing gaps produce better learning than shorter spacing gaps (Rawson & Dunlosky, 2011). According to Cepeda et al. (2006), the spacing effect has been documented in hundreds of publications using a wide variety of leaner ages. Benefits of spacing has shown improvement in learner outcomes in both children (Rea & Modigliani, 1985; Toppino & Gerber, 1984) and adults (Balota, Duchek, & Logan, 2007). Probably the most robust effects of spacing occur in improved rote memory for the studied material (Cepeda et al., 2006). Across 254 studies comparing massed versus spaced practice on later memory for verbal information (e.g., words, sentences, facts, passages), overall, spaced practice dominated massed practice in student retrieval performance (Cepeda et al., 2006). According to the empirical data on optimal spacing gap, there is still some controversy among various researchers as to how much time is best. However, regardless of spacing gap, the student performance outcomes were all positive. Therefore, further investigation is needed at the graduate healthcare level to enrich the overall body of evidence in the current literature.

In summary, both active learning and spaced retrieval practice have shown positive results in terms of student key learning outcomes. As calls from dental accrediting bodies are answered, these instructional techniques could prove beneficial for structuring dental education for key student performance outcomes and professional competencies. As dental education prepares students for life-long learning, these

instructional techniques could foster a student-centered learning environment for deeper understanding of core course material. One key performance outcome is student self-assessment where a deeper understanding of core course material is crucial in evaluating personal performance outcomes. Self-assessment requires a reprogramming of student overall thought processes and a deeper cognitive approach to learning. Therefore, this literature review will now review three aforementioned cognitive theories as a lens to support student self-assessment activities as a key performance outcome in dental education. Consequently, a major goal of using active learning simulation and spaced instruction is to foster a learning environment that promotes deeper cognitive processes through self-directed learning.

Cognitive and Constructivist Learning Theories

The cognitive learning theory is a broad theory that explains thinking and differing mental processes and how they influence learning. (Sweller & Paas, 2017). Cognitive theories focus on students' learning processes and how information is obtained, assimilated, retained and retrievaled by the mind. Knowledge acquisition is concerned with what they know and how they come to acquire it, not what they do (Jonassen & Land, 2000). Knowledge acquisition has been defined as a mental activity that needs internalization and structuring by the learner where the learner actively participant in the process (Wilson & Cole, 1991). The term transfer is coined within the cognitive learning theory as a description of how information is stored in one's memory (Schunk & Zimmerman, 1994). Within the understanding of the process of learning, students can identify gaps or misunderstandings in their knowledge and modify how that information is processed (Nagowah & Nagowah, 2009). For example, when a learner understands

how to apply knowledge acquired in various contexts, then transfer of that knowledge has occurred. In dental education, transfer of the knowledge and skills used for self-assessment can promote self-regulated learning and pave the path to professional competencies.

The constructivist theory on learning is a broad-based theory that explains how people might acquire knowledge and learn (Fosnot, 2005). Constructivism focuses on the idea that learning occurs after creating meaning through life experiences (Duffy & Bednar, 1991). Many cognitive psychologists think of the mind as a gateway to the world; however, constructivists believe that the mind filters input from the world to produce its own individual reality (Jonassen, 1991). Brown, Collins, and Duguid (1988) suggest that situations actually co-produce knowledge (along with cognition) through activities. Every action is viewed as an interpretation of the current situation based on an entire history of previous interactions (Fosnot, 2005). The constructivist position assumes that transfer can be facilitated by involvement in authentic tasks anchored in meaningful contexts. Since understanding is "indexed" by experience, the authenticity of the experience becomes critical to the individual's ability to use ideas (Brown et al., 1988). In dental education, hands-on simulated activities through formative instruction may promote the needed experiences for students to create meaning of conceptual knowledge.

Cognitivist teaching methods aid to help students in connecting new information to previous knowledge while helping them modify existing knowledge (Bower & Hilgard, 1981). Some common cognitive instructional strategies may include the use of framing, outlining, mnemonics, concept mapping, advance organizers, simulation, self-assessment and so forth (West, Farmer, & Wolff , 1992). For dental students learning

self-assessment and how to modify behaviors, cognitivist theory on education stresses the process of learning (Ertmer & Newby, 2008).

Metacognition Theory of Learning

Flavell (1979) coined the term metacognition in the late 1970s to mean "cognition about cognitive phenomena," or, more simply, "thinking about thinking" (p. 906). As Susser and McCabe (2013) explain, metacognition is what enables a student who has been taught a particular strategy in a particular problem context to retrieve and deploy that strategy in a similar but new context. In cognitive psychology, metacognition is often defined as a form of executive control involving monitoring and self-regulation, a point reinforced by other researchers (Bjork et al., 2013; Karpicke & Roediger, 2010; Kostons et al., 2012).

Roediger and Karpicke (2006) suggested that traditional curricula and instructional practices are insufficient for promoting metacognitive thinking. Rather, elements such as explicit focus on learning processes or emphasis of deep understanding are necessary. As a result, students tend not to use or refine their metacognitive strategies over time in this education environment. More often, the features necessary for fostering metacognitive learning seem to be absent during regular lessons, even though many of these features are associated with positive gains in achievement over time (Bjork et al., 2013; Karpicke & Roediger, 2010; Kostons et al., 2012). In the pursuit to promote self-regulated learners, the art of refining or fostering metacognitive abilities should be of primary focus. Dental students that can apply self-assessment skills across procedures

and in different contexts will achieve professional competency and reduce poor clinical outcomes.

One of the critical features of the learning environment for fostering metacognitive strategy use is an engaging curriculum (Bjork et al., 2013; Kostons et al., 2012). A curriculum which integrates student interest, active learning, and collaboration affords frequent opportunities for students to use metacognitive thinking skills. Likewise, as McCabe (2011) suggests, traditional teaching practices do not encourage students to reflect on their thinking. For example, the characteristics of an engaging curriculum, such as constructivism, self-direction, and transfer are often used infrequently in comparison to more direct methods such as whole class instruction (Karpicke & Roediger, 2010).

Nevertheless, adjusting a curriculum to be more engaging for students can have a substantial effect on the quality and quantity of metacognitive strategy use. Some general examples for making a curriculum more engaging include integrating student choice, problem-based learning, concept teaching, self-assessment and simulations (Bjork et al., 2013; Karpicke & Roediger, 2010; Kostons et al., 2012). Providing consistent practice opportunities is another feature for fostering metacognitive strategy use (Kornell & Bjork, 2007). Kostons, van Gog and Paas (2012) suggests teaching multiple metacognitive strategies, such as making predictions, visualizing, and summarizing. Kostons et al. (2012) also suggests that these strategies be used repeatedly across multiple lessons in order to produce tangible gains in student achievement. The most significant gains in student achievement result when students are taught the use of metacognitive strategies in explicit ways (Bjork et al., 2013; Karpicke & Roediger, 2010; Kostons et al., 2012). Characteristics of explicit teaching include direct instruction, modelling,

explaining the benefits of using the strategy, and providing repeated opportunities for using the strategy in guided and independent practice formats (Kornell & Bjork, 2007). However, providing consistent practice opportunities must be accompanied by some evaluation or feedback. Students should be prompted to judge the effectiveness of their learning method by considering past performance with respect to established goals (McCabe, 2011). Self-assessment is one critical way for students to judge the effectiveness of their conceptual knowledge and application of a course designed grading rubric.

Self-Efficacy Theory

Self-efficacy was coined by Albert Bandura's as part of a larger theory, the Social Learning Theory (Ashford, Edmunds & French, 2010), which has progressed into the Social Cognitive Theory (Levin, Culkin, & Perrotto, 2001). Self-efficacy is the belief in one's ability to influence events that effect one's life and control over the way these events are experienced. (Bandura, 1994). Simply, self-efficacy is what an individual believes he or she can accomplish using his or her skills under certain circumstances (Snyder & Lopez, 2007). The basic premise of Self-Efficacy Theory is that individuals are more likely to engage in activities for which they have high self-efficacy and less likely to engage in those they do not (Van der Bijl & Shortridge-Baggett, 2001). In dental education, students that achieve a level of self-efficacy for performing self-assessment skills can promote self-directed learning and progress towards professional competencies.

According to Gecas and Schwalbe (1983), people behave in the way that executes their initial beliefs; thus, self-efficacy functions as a self-fulfilling prophecy. Self-efficacy

is posited to influence individuals approach to learning, motivation, and subsequent performance, as people will often attempt to learn and perform only those tasks for which they believe they will be successful (Lisda & Harina, 2018). Bandura (1977) outlined four sources of information that individuals employ to judge their efficacy; performance outcomes (performance accomplishments), vicarious experiences, verbal persuasion, and physiological feedback (emotional arousal).

Williams and Williams (2010) note that "individuals with high levels of self-efficacy approach difficult tasks as challenges to master rather than as threats to be avoided" (Williams & Williams, 2010, p. 455). According to Bandura (1977), performance outcomes or past experiences, are the most important source of self-efficacy. If one has performed well at a task previously, he or she is more likely to feel competent and perform well at a similarly associated task (Bandura, 1977). Therefore, it is important that students maintain a high self-efficacy during self-assessment as the student moves towards professional competency (Lent, Brown, & Larkin, 1986). A high self-efficacy can be generated by placing students in low stakes environment where they pace their own learning (Komarraju & Nadler, 2013). Students that pace their own learning through endless formative experiences will pave their path towards being self-regulated learners (Chemers, Hu & Garcia, 2001).

According to Albert Bandura (2006), there is no self-efficacy scale that represents a general model for all domains or constructs. Therefore, scales of perceived efficacy must be designed to the particular domain of interest. Perceived self-efficacy can be a judgement of capability to execute certain kinds of performances (Bandura, 1996). Perceived self-efficacy has been confirmed as an influential role in human development,

adaptation and change across different constructs (Boyer et al., 2000; Holden, 1991; Holden, Moncher, Schinke, & Barker, 1990). Self-efficacy scales should then measure gradations of challenges to a successful performance (Bandura, 2006). In designing a self-efficacy scale, 0-10 response format is a stronger predictor of performance than one with a 5-interval scale (Pajares, Hartley, & Valiante, 2001). According to Bandura (2006), to minimize response bias, the scale should be anonymous, confidential and nondescript. While looking to develop a scale to measure student perceived self-efficacy towards performing self-assessment activities, these characteristics must be considered.

The appropriate development and use of a scaled assessment are essential requirements for responsible professional practice in educational testing and measurement (Slavic & Drnovsek, 2012). The American Educational Research Association (AERA), the American Psychological Association (APA), and the National Council on Measurement in Education (NCME) have collaborated on the development of Standards for Educational and Psychological Testing (Plake & Wise, 2014). Some of these standards should be considered in the development of a pilot instrument used in the study to gauge student confidence (self-efficacy) at performing key self-assessment tenants associated with a grading rubric following various instructional techniques.

The first professional standard that should be addressed is reliability; measurement reliability addresses the consistency of your instrument's measurement (Plake & Wise, 2014). For example, if you use a marked ruler to measure six inches in the light, you can reliably do this repeatedly. However, if you change the circumstances and darken the room, the reliability of an accurate measurement changes. Reliability of

an instrument can be tested with a test-retest evaluation or using Cronbach's Alpha Coefficient (Cronbach, 1968) for internal consistency.

The second professional standard that should be addressed is validity; measurement validity addresses how accurately the instrument measures the outcome or construct your intervention is attempting to affect (Plake & Wise, 2014). In this context, an instrument is valid if it actually measures what you intend it to measure. Items such as commercial rulers or scales are straightforward examples of instruments with strong measurement validity. However, the validity of a tool that attempts to measure growth in cognitive ability or increased behavior tendencies (such as increases in mobility) is not as clear. Content validity can be obtained through expert peer-review of the instrument content with numerous iterations teasing out non-construct related questions.

Self-assessment, in summary, gains theoretical support through four distinct theories of learning demonstrated in figure 1 below. The four theoretical frameworks can be viewed as pillars supporting the overall learning process of performing self-assessment. Constructivism focuses on the idea that learning occurs after creating meaning through life experiences (Duffy & Bednar, 1991). Cognitive theories focus on students' learning processes and how information is obtained, assimilated, retained and retrieved by the mind (Sweller & Paas, 2017). Metacognition is what enables a student who has been taught a particular strategy in a particular problem context to retrieve and deploy that strategy in a similar but new context (Susser & McCabe, 2013). Self-efficacy posits to influence individuals approach to learning, motivation, and subsequent performance, as people will often attempt to learn and perform only those tasks for which they believe they will be successful (Lisda & Harina, 2018). Each of these four theories,

in part, will collaboratively enhance student learning and promote meaningful self-assessment activities towards clinical competence. That is, if students can create understanding of self-assessment through many formative experiences, contextualize and retrieve information, modify behaviors through reflection and obtain a level of confidence needed to enhance the self-assessment

Figure 1.

Theoretical Pillars Supporting Self-Assessment

Note. Each theoretical pillar represents a unique and supportive leg that in part enhance student self-assessment capabilities.

Study Purpose

There were gaps in the current literature regarding how active learning and spaced retrieval practice could foster and promote key performance outcomes like self-assessment in dental education. The majority of dental schools, including ULSD, still utilize traditional instructional models to distribute core course information (Michael, 2006). This type of instructional model has been shown in the literature to promote

memorization of material for short-term retrieval of information (Morales, 2017; Sera & Wheeler, 2017; Tang & Chen, 2017). However, dental students' ability to retain, retrieve and apply grading criteria for self-assessment requires a deeper understanding of the foundation concepts (Tang & Chen, 2017). Dental school curricula should strive to employ innovative instructional techniques that enhance self-regulated learning through higher levels of engagement, critical thinking and self-reflection. It was imperative that dental education curricula reexamine current instructional techniques to promote long-term retention of material. The current singular and passive instructional technique at ULSD does not foster student engagement, creation of a low-stakes learning environment or enhance self-directed learning. (Metz et al., 2017).

Spaced retrieval practice posits that once a student grasps information enough to retrieve it, additional retrieval of that information will increase the likelihood of long-term retention (Karpicke, 2009; Karpicke & Reodiger, 2008). In addition, increasing interval exposures between retrieval opportunities increases the overall impact of retaining information (Cull, 2005; Hopkins, Lyle, Hieb & Ralson, 2015; Karpicke & Roediger, 2007). The application of spaced retrieval practice in dental curricula could place dental education on the correct path to promoting self-assessment skills. The current literature on active learning in general is compelling in the fact that it places the learners in control of their own learning creating a self-regulated learning environment (Arias et al., 2016; Morales, 2017; Sera & Wheeler, 2017). Specifically, patient active learning simulation activities has been shown to improve conceptual understanding and application of knowledge (Bommer et al., 2017; Lin & Song, 2017; Nilsson et al., 2017). Self-assessment activities require that students first understand the criteria for which they

are being assessed (Jackson & Murff, 2011; Kostons, van Gog & Paas, 2012). Once this understanding occurs, practical application of the material drives self-regulation and self-awareness for improvements through formative experiences (Jackson & Murff, 2011). Accurate self-assessment is the epitome of metacognition where students are thinking about their thinking and making improvements in their knowledge through identification of errors or gaps (Bjork et al., 2013; Roediger & Karpicke, 2010; Kostons et al., 2012).

It is imperative that ULSD provide a learning environment that student-centered and encourages self-regulated learning. Hand-skills are the one aspect that students rarely get to prepare for prior to entering dental school. Additionally, hand-skills performance are not part of the admissions process for any dental school in the United States. Therefore, the majority of students are truly novice at self-assessment activities resulting in overinflated or erroneous self-evaluations. The current issue faced is that students are still learning their self-assessment skills while in patient care when they should be honing them. The delay in self-assessment skills is believed to be the current instructional model and the lack of student development time in the current curriculum at ULSD. The first goal for this study was to provide quantitative data to make evidence-based decisions for the future of dental education and the curriculum at ULSD. Additionally, a second goal was to provide a learning environment for students that promotes self-regulated learning while satisfying mandates from governing entities like CODA. For this study, it was hypothesized engaging students through active learning (simulation) and spaced retrieval practice will significantly improve students' conceptual knowledge and clinical application of the grading criteria compared to the current passive model. Additionally, students will feel more confident (higher self-eeficacy) in their ability to apply

knowledge learned. With the current limitations and gaps in the published literature, the research sought to address the following research questions: 1.Does spaced retrieval practice and active learning (simulated) improve students' memory retention, retrieval and application of objective grading criteria used for self-assessment compared to a traditional lecture? 2. Does spaced retrieval practice and active learning (simulated) improve students' reported self-efficacy towards applying key grading criteria used for self-assessment compared to a traditional lecture?

The purpose of this study was to evaluate active learning (simulation) and spaced retrieval practice as instructional techniques to foster student preparation for self-assessment activities. It was hypothesized that students exposed to a learning environment that engages them in self-regulated practices with retrieval opportunities will foster a deeper understanding of core course material through deeper cognitive practices. This allowed time for students to have more experiences in which self-assessment truly mends deficiencies in their hand-skills. According to CODA (CODA, 2019), this is what will create a self-regulated, life-long learner. Additionally, results from this study provided quantitative data to suggest curricular innovations at the school of dentistry in keeping with directives from CODA. Under investigation is whether the concept of spaced instruction alone or in combination with simulated active instruction can improve student self-assessment scores through memory retention, retrieval and clinical application when compared to traditional instructional techniques.

The information gained from this research project is key in challenging the current passive curricular model used for hand-skills courses at ULSD. As ULSD strives to improve its curriculum during this extensive review process, this study yielded

empirical evidence that can be utilized for critical decisions that aim to meet CODA directives and student performance outcomes. Additionally, the empirical evidence from this study filled gaps in the literature on spaced retrieval practice and active learning at the graduate healthcare level. Previously, there was a gap in the education literature on using active learning in combination with spaced retrieval practice in the professional school environment. Lastly, the empirical evidence helped create the optimal learning environment for students to learn about self-assessment and its relationship to clinical competence, self-efficacy and life-long learning.

CHAPTER 3

METHODS AND MATERIALS

The purpose of this research was to examine the effectiveness of instructional techniques using engagement and spacing strategies to promote students' self-assessment knowledge retention, retrieval and clinical application of grading criteria. The study included two independent variables, each with two levels: engagement (engagement, no engagement) and spaced retrieval practice (spaced retrieval, no spaced retrieval). Dependent variables included students' content knowledge retrieval, content knowledge application regarding the use of a dentoform assessment, and perceived self-efficacy to self-assess their confidence in performing tasks associated with self-assessment. Based on random assignment of 120 D1 dental students to one of the four instructional technique groups in the preclinical operative dentistry course (CMPD-802), two research questions were addressed:

1. Does spaced retrieval practice and active learning (simulated) improve students' memory retention, retrieval and application of objective grading criteria used for self-assessment compared to a traditional lecture?

2. Does spaced retrieval practice and active learning (simulated) improve students' reported self-efficacy towards applying key grading criteria used for self-assessment compared to a traditional lecture?

Sample Selection and Participants

Study participants included a convenience sample of one hundred twenty (*n*=120)

D1 dental students. Inclusion criteria was that the D1 dental students were officially

enrolled in CMPD-802 (preclinical operative dentistry I lecture and laboratory) which is a

single course section for all D1 dental students. According to the files from the DMD

admissions office, this cohort of D1 dental students consists of 52% males, 46% females,

and 2% other. This cohort represents a diverse racial group with 75% Caucasian, 15%

African American, 5% Asian American, 3% Alaska Native, and 2% Pacific Islander.

Further, 56% of D1 dental students were in-state and 44% out-of-state. Entry-level mean

GPA was 3.88 (SD 0.52) (4.0 scale) representing 27 undergraduate college institutions

with a mean DAT score of 21 (30 highest score). According to the most recent

publication of DMD admissions from the American Dental Education Association

(ADEA, 2020), the demographics at ULSD are similar to other dental education

institutions across the United States. Therefore, this sample of students was considered

comparable across all accredited dental schools in the United States. Results drawn from

this cohort of D1 dental students should be representative of all accredited dental

education institutions across the United States.

Consent and Data Privacy

All participants were provided an IRB approved preamble letter informing them

of their rights to withhold their specific achievement scores if so inclined without

repercussions. The informational letters addressed the reasons for this study and what

specific data was accessed. Participants were provided the primary investigators contact

information as well the HSPPO contact information. Additionally, participants were provided specific instruction if they so elected to not have their response scores part of the research. The study falls into normal educational practices for preparing students for assessment of operative dentistry experiences. All participants were over the legal age of eighteen and possessed the mental capacity to consent. The risks associated with this study are minimal; however, students could have withdrawn their performance scores from the study at any time without fear of repercussions. All data were stored on an encrypted external hard drive (IronKey; Imation) and password protected provided by the information technology (IT) department at the UofL School of Dentistry. All participants were blinded to the results of study regardless of group assignment. The primary investigator was not blinded to the group assignments but was blinded to all group assessment scores.

Research Design

A 2 X 2 factorial design with engagement (no engagement, engagement) and spaced retrieval practice (no spaced retrieval, spaced retrieval) as the independent variables was used to address the aforementioned study research questions. Dependent variables included: Students' retention and recall of learned information, application of learned information (dentoform assessment), and self-assessment self-efficacy. Specifically, dental students were randomly assigned to one of four study conditions: No Engagement, No Spaced Retrieval Practice (control condition; 1:1); No Engagement, Spaced Retrieval Practice (1:2); Engagement, No Spaced Retrieval Practice (2:1); and, lastly, Engagement, Spaced Retrieval Practice (2:2). Table 1 below provides a visualization of the study's experimental design.

Table 1.

Factorial Research Design

2X2 Factorial Research Design		Level of Engagement	
		No Engagement 1 N=60	Engagement 2 N=60
Use of Spaced Retrieval Practice (SRP)	No Spaced Retrieval Practice 1 N=60	No Engagement and No Spaced Retrieval Practice 1:1 Group 1 (N=30)	Engagement and No Spaced Retrieval Practice 2:1 Group 3 (N=30)
	Spaced Retrieval Practice 2 N=60	No Engagement and Spaced Retrieval Practice 1:2 Group 2 (N=30)	Engagement and Spaced Retrieval Practice 2:2 Group 4 (N=30)

As reported, the dependent variables are two performance-based outcomes operationalized based on students' performance on a multiple-choice exam administered four weeks post baseline to assess knowledge retention and retrieval. The second dependent variable, which was operationalized using a hands-on simulated dentoform scoring assessment administered six weeks post baseline. Assessed was knowledge retention, retrieval and application of the self-assessment criteria. In addition, a third dependent variable, self-assessment self-efficacy, was assessed six weeks post baseline

using a self-report survey to operationalize students' confidence levels at performing self-assessment activities.

Figure 2 below provides a visualization of the study's experimental design and outcome measurements. The study design flowchart represented by Figure 2 contains group assignments and outcome assessments across a six-week timeline. One hundred twenty D1 dental students were randomly assigned to one of four treatment groups representing different instructional techniques. All groups were administered a 30-question multiple choice examination four weeks post intervention followed by a hands-on dentoform assessment and self-reported confidence survey six weeks post intervention. The timeline was created to visualize the overall study design and at which time increments performance outcomes were assessed. A detailed explanation of the study design follows Figure 2.

Figure 2.

Study Design Flowchart.

Group Assignments

Group 1 (1:1)	No ENG and No SRP (n=30) (Control Group)
Group 2 (1:2)	No ENG and SRP (n=30) → No ENG and SRP (n=30)
Group 3 (2:1)	ENG and No SRP (n=30)
Group 4 (2:2)	ENG and SRP (n=30) → ENG and SRP (n=30)

Outcome Assessments

Baseline — 2 Weeks — 4 Weeks — 6 Weeks
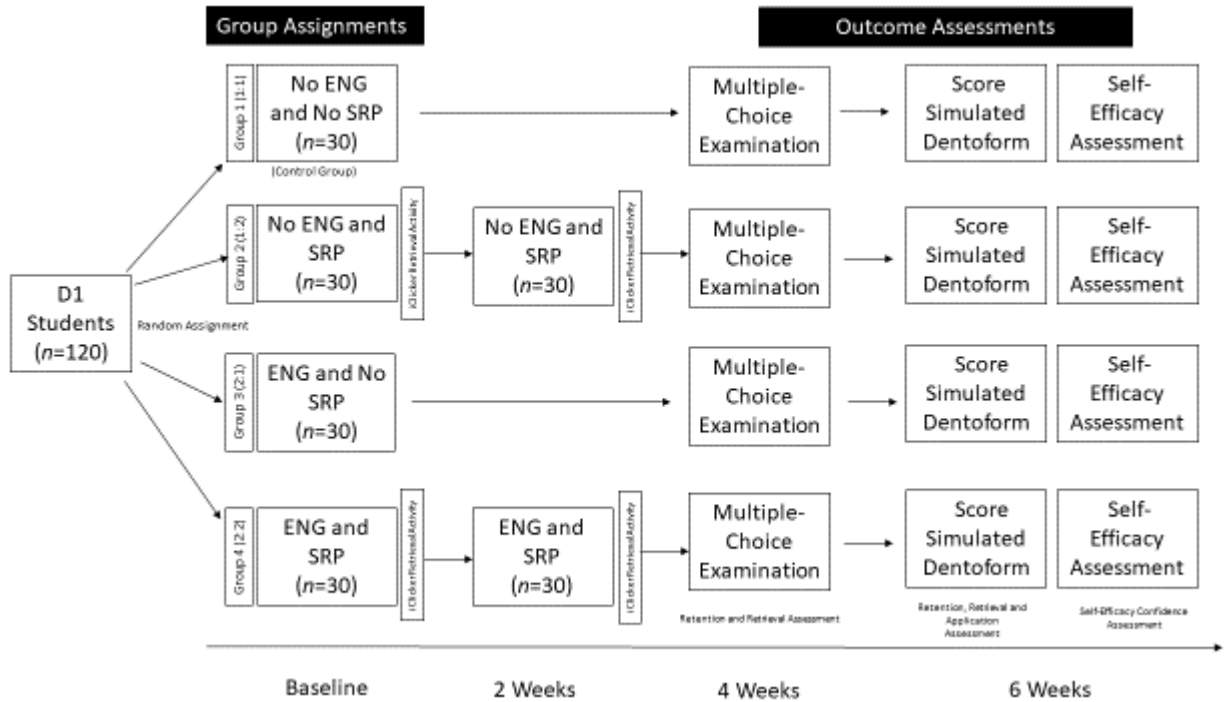
Traditional Instruction (Control-Group 1, 1:1.) This group assignment represents no engagement of course content and no spaced retrieval practice (*n*=30). This is the current instructional format deployed at the ULSD and was the control group. Within this condition, students received a 90-minute PowerPoint presentation covering the course content needed for self-assessment. Total instruction time for this group was one 90-minute session

Traditional Instruction and Spaced Retrieval Practice (Group 2, 1:2.) This group assignment represents no engagement of course content and spaced retrieval practice (*n*=30). Students received the same 90-minute PowerPoint presentation broken into two 45-minute sessions separated by two weeks. At the end of each session, students were administered a ten-question iClicker quiz to provide students the opportunity to

retrieve key tenants needed for self-assessment from that lecture. Total instruction time for this group was 90 minutes consisting of two 45-minute sessions.

Engaging Instruction (Group 3, 2:1.) This group assignment represents engagement of course content and no spaced retrieval practice (n=30). Students received the same 90-minute PowerPoint presentation with simulated active learning hands on application of self-assessment criteria throughout. Total instruction time for this group was one 90-minute session.

Engaging Instruction and Spaced Retrieval Practice (Group 4, 2:2.) This group assignment represents engagement of course content and spaced retrieval practice (n=30). Students received the same 90-minute PowerPoint presentation broken into two 45-minute sessions separated by two weeks. Simulated active learning hands on application of self-assessment criteria was dispersed throughout the two sessions. Additionally, at the end of each session, students were given a ten-question iClicker quiz allowing students to retrieve key tenants needed for self-assessment from that lecture. Total instruction time for this group was 90 minutes consisting of two 45-minute sessions.

Within the factorial ANOVA design, success of the instructional techniques in this study was evaluated by testing the statistical significance of the main effect of engagement and spaced retrieval practice for each of the three dependent variables, namely: a multiple-choice examination, a hands-on assessment of a simulated dentoform activity, and self-assessment self-efficacy. In addition, the interaction of engagement and spaced retrieval practice on dependent variables was also examined.

The first dependent variable, students' content knowledge of the grading rubric criteria was operationalized using a 30-item multiple-choice assessment. At four weeks post baseline, all groups completed the assessment designed to measure knowledge retention and retrieval of self-assessment criteria used for self-assessment. Raw scores ranging from 0 (none correct) to 30 (all correct) were used to measure this continuous dependent variable. The raw scores achieved on this multiple-choice examination represented the memory retention and retrieval of criteria used for self-assessment. Higher scores then represent better memory retention and retrieval of the grading criteria used for self-assessment. The main objective was to see how students would theoretically apply content from the grading rubric onto the peer and self-assessment form. The questions on the multiple-choice examination were peer-reviewed and edited by seven calibrated faculty suggesting that the instrument has adequate content validity. Data from two previous grading classes (2016 and 2017) that took the examination has been entered into SPSS to check the internal reliability (n=237). Cronbach's Alpha was 0.76, which indicates a moderate level of internal consistency for the examination (Cronbach, 1969). An item analysis reported that removal of any question would only decrease the overall reliability (i.e., Cronbach's coefficient alpha).

The second dependent variable, students' content knowledge recall, retrieval and application of the grading rubric criteria was assessed using a simulated dentoform activity. In particular, all groups at six weeks post baseline scored a simulated dentoform activity covering self-assessment criteria. The ULSD peer and student self-assessment form was used to score the simulated dentoform activity. A detailed explanation of the assessment form and associated grading rubric will be discussed in detail later in chapter

3. Students and faculty use this form for all hand skills peer and self-assessment activities in operative dentistry at ULSD. Raw scores ranging from 0 (excessive deficiencies) to 36 (no deficiencies) was used to measure this continuous dependent variable, with higher scores indicative of less detectable deficiencies in the simulated project. The raw scores achieved on this simulated dentoform activity represented the memory retention, retrieval and application of criteria used for self-assessment. All students were provided a simulated patient profile in axiUm (dental charting software) with corresponding bitewings radiographs and medical history, and will subsequently evaluate two dentoform models: one with a class II mesial-occlusal preparation to be restored with resin composite and one with the restoration completed. Students were asked to access the dentoform on the peer and self-assessment form retrieving the objective grading criteria in the grading rubric. The simulated case was prepared and graded by all seven calibrated faculty and determined to have a mean score of 25.14 (±0.90) This score is interpreted as an acceptable project with a few noticeable deficiencies that should be identified by adequately trained students. Therefore, measured will be the students' ability to discern and apply grading criteria used for self-assessment.

The third dependent variable included students reported self-efficacy. At six weeks post baseline, all groups completed a 10-item self-report survey based on a 10-point Likert style scale survey to assess their confidence level in applying certain key tenants needed for accurate self-assessment. Raw scores ranging from zero (low confidence level) to ten (high confidence level) were used to measure this continuous dependent variable. The raw scores achieved on this questionnaire represent students perceived self-efficacy (or confidence) towards applying key concepts. Higher scores

then represented higher self-efficacy (or higher confidence level). The main objective is to see how the different instructional techniques may influence student self-efficacy in performing self-assessment activities. The questions on this instrument were designed specifically for gauging this course content in operative dentistry following guidelines located in Albert Bandura's *Guide for Constructing Self-efficacy Scales* (Pajares & Urdan, 2007).

Instructional Materials and Group Presentations

All groups were exposed to the same curriculum throughout course lectures based on a PowerPoint presentation under the same environmental conditions. All instructional techniques began at 9:00am E.S.T. in the same dental school classroom (DE 124) by a calibrated operative dentistry faculty well versed in active learning on days which accommodate the current curriculum. The course content is a combination of written guidelines located within the grading rubric and simulated photographs to represent certain grading criteria standards. The information contained within the PowerPoint presentation was peer-reviewed by seven calibrated dental school faculty to ensure consensus among experts representing content validity of the material. The current PowerPoint presentation was designed to be a single ninety-minute instructional tool that exposed dental students to conceptual knowledge and clinical application of the grading rubric. Student understanding of the conceptual content, retrieval and clinical application of the grading rubric was used to provide a self-assessment of their hands-on work.

Peer and Self-Assessment Instrument

The peer and self-assessment form is administered within the ULSD within all operative dentistry experiences at ULSD (see Appendix A for the peer and student self-assessment forms). This form was the source of data for the simulated dentoform activity used to measure the second dependent variable. This section details the peer and self-assessment form and how was administered to D1 students. The peer and self-assessment form is used at the school of dentistry allows students to apply the concepts within the grading rubric to their individual hands-on performances in operative dentistry. All dental students were asked by the discipline coordinator of operative dentistry to perform self-assessment on all preclinical and clinical operative dentistry experiences following the posted grading rubric. It is only after the student provides their self-assessment that a covering faculty will provide a peer-assessment on the same form. Therefore, accuracy of the student self-reflection becomes a graded feature for the faculty to evaluate located on the self-assessment form.

The peer and self-assessment form is divided into three sections: overall experience, preparation design principles, and restoration design principles. In the overall experience section, graded areas are preparedness (intellectual autonomy), clinical judgment (confidence in reasoning), critical thinking, self-assessment, infection control, biomedical application and professionalism (intellectual empathy). In the preparation design principles section, graded areas are outline form, retention form, resistance form and modification requests. In the restoration design principle section, graded areas are anatomical form, marginal integrity, proximal contact placement and embrasure form. Overall peer and self-assessment form scores are calculated using the following standardized grading scale: 3 (*Exceptional*), 2 (*Acceptable*), and 0 (*Unacceptable*).

Therefore, a mean overall score must meet or exceed a score of 2 to be considered a successful experience. In each of the three sections there are four areas of assessment resulting in twelve overall individual grades. Each of the twelve scores are weighted equally in determining the overall score for the experience. The maximum total points allowed on the peer and self-assessment instrument is thirty-six (3 X 12= 36). For this research project, the total score out of thirty-six for each student will be used on the simulated dentoform activity (dependent variable 2). 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 or equal to two (2= *Acceptable*).

All faculty evaluations for operative dentistry hand skills courses are performed by calibrated dental faculty following the course rubric. The simulated dentoform activities associated with this studies outcome assessment were evaluated by all seven-competency grading faculty and the scores averaged. A mean overall score of the seven calibrated faculty was determined to be 25.14 (±0.90). The overall mean score from the calibrated faculty can be interpreted as a project with some identifiable deficiencies in the simulated project that need to be detected by the students. The instructional technique group(s) that score in the range of the faculty score will be considered to have better retention of the information, better retrieval of the information and better able to apply the concepts clinically. These seven graders have a mean time of working in dental education at ULSD of 14 years ± 4 years. Two of the seven graders are board certified by the American Board of Operative Dentistry and all seven graders have been peer-selected to national dental license organizations. Evaluation of the graders during the most recent

calibration session shows the following Cohen's Kappa: $k = 0.87$, $p < .05$. The average

Pearson's Correlation among the seven graders was 0.86. The director for operative

dentistry finds any Cohen's Kappa above 0.70 acceptable agreement among raters. The

data from the most recent calibration session suggested a strong agreement and strong

positive correlation among the seven graders (Landis & Koch, 1977).

Grading Rubric

The grading rubric intimately follows the peer and self-assessment instrument to

provide set grading criteria for each graded section to suggest a scoring range for each of

the twelve graded areas. Within each graded section are critical errors denoted that would

result in an overall failure for the examination of competence. A copy of the grading

rubric can be found in Appendix B. The grading rubric was designed to help students and

faculty objectively score experiences for consistent feedback and to promote student self-

regulated learning. The grading rubric was designed through consensus of all seven

calibrated faculty and has been deployed for three years. As students and faculty score

the assessment form (3-2-0), the grading rubric follows in order the steps of the

restorative process. Specific details in the grading rubric guide students and faculty to

how the grades 3-2-0 are achieved. The rubric is used to reduce or eliminate subjectivity

in scoring process to promote student self-regulated learning and faculty calibration.

Data Collection and Analysis

The descriptive statistics were first evaluated to gain a better understanding of the

characteristics of the data and students standing on the dependent variables. According to

Tabachnick and Fidell (2007), descriptive statistic evaluation helps in describing,

summarizing or showing data in a meaningful way.

A 2 X 2 factorial (two-way) ANOVA was conducted for hypothesis testing

(Tabachnick & Fidell, 2007). This includes testing for the main effects of Factor A

(engagement) and Factor B (spaced retrieval practice), in addition to an interaction effect

(engagement x spaced retrieval). Null hypothesis testing was based on $p < .05$,

respectively. A Levene's Test of Equality of Error Variances was performed on all three

of the analyses for each dependent variable to test the null hypothesis that the error

variance of the dependent variable is equal across groups. A non-significant Levene's

Test indicates equal variance across levels of the independent variable ($p > .05$). Provided

significant main effects, Cohen's d was used for quantifying the magnitude of difference

between significant pairwise comparisons (> 0.2 small, > 0.5 medium, and $> 0 .80$ large;

Cohen, 1977). For a significant interaction effect, a simple effects analysis was conducted

to identify which of the group means were statistically significantly different, $p < .05$. All

analyses were performed using SPSS statistical software package version 26 (IBM, inc.)

An a priori power analysis was performed using G-Power software to determine

the appropriate sample size for this evaluation (Cohen, 1988). With a type I error rate of

$p < .05$, a type II error rate of 0.8 and a moderate effect size of 0.25, the power analysis

determined that the total sample size needed was eighty-five ($N = 85$) or twenty-one ($n =$

21.25) per group for population inference. With 30 students per group, the study was

sufficiently powered.

According to Campbell and Stanley (2005), there are several factors to consider that could jeopardize the internal and external validity of an experimental research design. Internal validity was defined as the basic minimum without which any experiment is uninterpretable (Campbell & Stanley, 2005). External validity was defined as how generalizable the results are to the population (Campbell & Stanley, 2005). According to most current data released by the ADEA, ULSD is very similar to the other accredited dental schools in terms of students' admissions demographics, DAT scores and entering GPA scores. Therefore, it is important to relate sources of potential invalidity that should be considered and means to control them as confounding variables.

Specific threats to internal invalidity for this experimental research design included history, maturation, testing, instrumentation, regression, selection and mortality (Campbell & Stanley, 2005). History was controlled in this study by testing all four treatment groups at the same time and in the same setting. Maturation and testing was controlled for this study in that they are manifested in all groups equally. Instrumentation was controlled by using the same assessment form and grading rubric for all treatment groups. Regression was controlled by randomization of the treatment groups resulting in similar regression across groups. Selection bias was controlled by randomization of participants into treatment groups. Mortality was controlled by having a short experiential design over six weeks. Sources of external invalidity for this experimental research design are situational factors, sample features and selection bias (Campbell & Stanley, 2005). Situational factors were controlled to improve the generalizability of the results by utilizing a standard lecture auditorium that most dental schools possess. Additionally, utilizing a peer-reviewed and popular dental textbook for preparation and restoration

guidelines that all dental schools have access to (Heymann, Swift, Ritter & Sturdevant, 2018). Sample features were controlled in that all dental admissions utilize similar criteria for admitting dental students (CODA, 2019) on a diverse population of candidates. Therefore, the results should translate well to all D1 dental students attending CODA approved dental schools in the United States. Selection bias was controlled by inviting all D1 dental students to participate in this study and randomization of group assignments.

CHAPTER 4

RESULTS

A two-way ANOVA was conducted for hypothesis testing across the study's three dependent variables. This includes testing for the main effects of Factor A (engagement) and Factor B (spaced retrieval practice), in addition to an interaction effect (level of engagement x use of spaced retrieval practice). Null hypothesis testing was based on $p < .05$, respectively. A Levene's Test of Equality of Error Variances was used to test the model assumption of equal variance of the dependent variable across groups. A non-significant Levene's Test indicates equal variance across levels of the independent variable. For significant main effects, Cohen's d was used for quantifying the magnitude of difference between group means (> 0.2 small, > 0.5 medium, and > 0.80 large; Cohen, 1977). For a significant interaction effect, a simple effects analysis was conducted to identify which of the group means were statistically significantly different, $p < .05$. Study findings are subsequently presented.

Multiple Choice Examination Scores

As a review, higher scores on the multiple-choice examination represented better retention and retrieval of core content material needed for self-assessment. Table 2 reports the descriptive statistics for the multiple-choice examination scores. Group 1, which represented the control group within the study (no engagement and no spaced

retrieval practice; n = 30), scored a group mean score of M =17.13 (SD = 5.06), which

was the lowest overall mean score of the groups. Group 2 (no engagement and spaced

retrieval practice; n = 30) scored a group mean score of M = 22.70 (SD = 5.10). Group 3

(engagement and no spaced retrieval practice; n = 30) scored a group mean score of M =

24.00 (SD = 2.70). Group 4 (engagement and spaced retrieval practice; n = 30) scored a

group mean score of M = 26.63 (SD = 2.06), which was the highest overall mean score of

the groups. The total mean score for all students that received no engagement was M =

19.92 (SD = 5.76; n = 60) compared to all students that received engagement with a

mean score of M = 25.32 (SD = 2.73; n = 60). Also, the total mean score for all students

that received no spaced retrieval practice was M = 20.57 (SD = 5.31; n = 60) compared

to those students who received spaced retrieval practice with a mean score of M = 24.67

(SD = 4.34; n = 60). As reported, the grand mean for the entire sample (n = 120) was

22.62 (SD = 5.25).

Table 2

Descriptive Statistics for Multiple-Choice Examination

Multiple-Choice Examination Scores

Engagement Level	Spaced Retrieval Practice	Group	n	M	SD
No Engagement	No Spaced Retrieval Practice	1	30	17.13	5.06
	Spaced Retrieval Practice	2	30	22.70	5.10
	Total		60	19.92	5.76
Engagement	No Spaced Retrieval Practice	3	30	24.00	2.70
	Spaced Retrieval Practice	4	30	26.63	2.06
	Total		60	25.32	2.73

Total	No Spaced Retrieval Practice	60	20.57	5.31
	Spaced Retrieval Practice	60	24.67	4.34
	Total	120	22.62	5.25

Model Assumptions

To evaluate the assumption of homogeneity of variance, a Levene's Test of

Equality of Variance was performed to test the null hypothesis that error variance of the

multiple-choice examination scores were equal across groups. It was determined that this

test was significant at $p < 0.05$. Therefore, the null hypothesis was rejected suggesting

that the error variance of the multiple-choice examination scores were not equal across

groups. However, it was decided to move forward with the ANOVA testing not meeting

this assumption. To evaluate the assumption of normality mathematically, a Shapiro-Wilk

test was performed to test the null hypothesis that the multiple-choice scores were not

normal distributed across all levels of the independent variables. It was determined that

all combinations of engagement level and use of spaced retrieval practice were not

significant across the multiple-choice scores. To evaluate the assumption of normality

graphically, Q-Q plots were created for all combinations of engagement level and use of

spaced instruction across multiple-choice scores. The graphic representation supported

the Shapiro-Wilk test with the creation of a diagonal line from the data points. To

evaluate the assumption of no outliers, boxplots were created for each combination of

engagement level and use of spaced retrieval practice across multiple-choice scores.

There was a single outlier (case 82) for the combination of active engagement and no

spaced retrieval practice who scored a 30/30 on the multiple-choice examination. The

single outlier was not removed from the analysis and the ANOVA analysis was continued forward.

Analysis of Variance Testing

The main effect of engagement was statistically significant $F(1, 116) = 55.43$, $p <$ .05. Therefore, the null hypothesis was rejected for this between subject's evaluation. The main effect of engagement yielded a partial eta squared value of 0.323 suggesting 32.3% of the variance in the multiple-choice examination scores can be explained by engagement level. The results indicate that the multiple-choice scores were significantly greater for engagement ($M = 25.32$, $SD = 2.73$) than for no engagement ($M = 19.92$, $SD = 5.76$). Figure 3 below represents the overall mean scores on the multiple-choice examination comparing students not engaged to students engaged. Students that were engaged scored on average 5.40 points higher than students not engaged. Cohen's *d* was 1.20 indicating a large magnitude difference between these two mean scores.

Figure 3

Overall Mean Scores for Engagement Level on Multiple-Choice Examination

30

27   25.32

24

21   19.92

18

15

Mean Assessment Scores

No Engagement   Engagement

Engagement Level
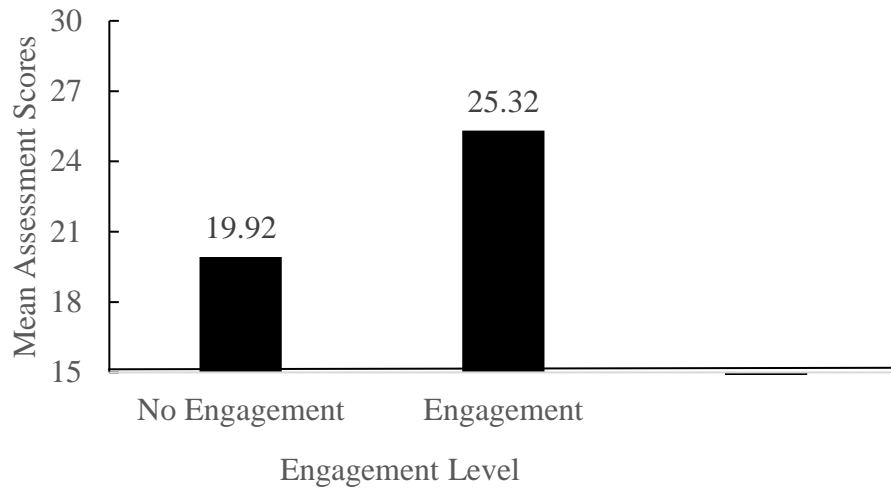
The main effect of factor B, spaced retrieval practice, was statistically significant, $F(1, 116) = 31.95$, $p < .05$. Therefore, the null hypothesis was rejected for this between-subjects evaluation. The main effect of spaced retrieval practice yielded a partial eta squared value of 0.216 suggesting 21.6% of the variance in the multiple-choice examination scores can be explained by spaced retrieval practice. The results indicate that the multiple-choice examination scores were significantly higher using spaced retrieval practice ($M = 24.67$, $SD = 4.34$) than not using spaced retrieval practice ($M = 20.57$, $SD = 5.31$). Figure 4 below represents the overall mean scores on the multiple-choice examination comparing students using spaced retrieval practice to those that are not. Students that utilized spaced retrieval practice scored on average 4.10 points higher than students not utilizing spaced retrieval practice. Cohen's d was 0.79 indicating a large magnitude difference between these two mean scores.

Figure 4

Overall Mean Scores for Spaced Retrieval Practice on Multiple-Choice Examination
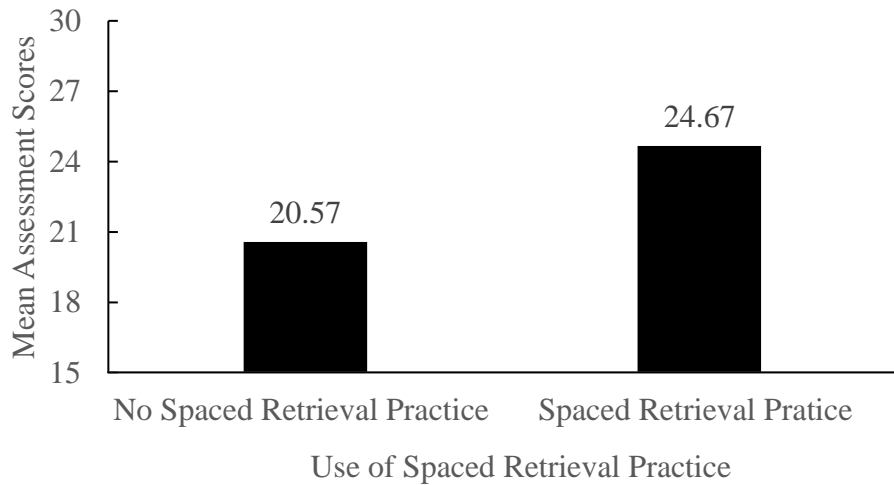
The interaction effect of engagement level and use of spaced retrieval practice was statistically significant, $F(1, 116) = 4.09$, $p < .05$, indicating the combination of engagement and spaced retrieval practice resulted in different knowledge scores. Subsequently, a simple main effects analysis and pairwise comparison was ran to further investigate the significant interaction of engagement level and use of spaced retrieval practice on multiple-choice examination scores. Figure 5 indicates that students that are engaged ($M = 24.00$; $SD = 2.70$) score significantly higher (6.87 points) than students not engaged ($M = 17.13$; $SD = 5.06$) receiving no spaced retrieval practice, $p < .05$. The results indicate that students that are engaged ($M = 26.63$; $SD = 2.06$) score significantly higher (3.93 points) than students not engaged ($M = 22.70$; $SD = 5.10$) receiving spaced retrieval practice, $p < .05$. Students that receive spaced retrieval practice ($M = 22.70$ $SD = 5.10$) score significantly higher (5.57 points) than students not receiving spaced retrieval practice ($M = 17.13$; SD = 5.06) when not engaged, $p < .05$. The results indicate that students that receive spaced retrieval practice ($M = 26.63$; $SD = 2.06$) score

significantly higher (2.63 points) than students not receiving spaced retrieval practice (*M* = 24.00; SD = 2.70) when engaged, *p* < .05.

Figure 5

Interaction Effect on Multiple-Choice Examination Controlling for Engagement Level
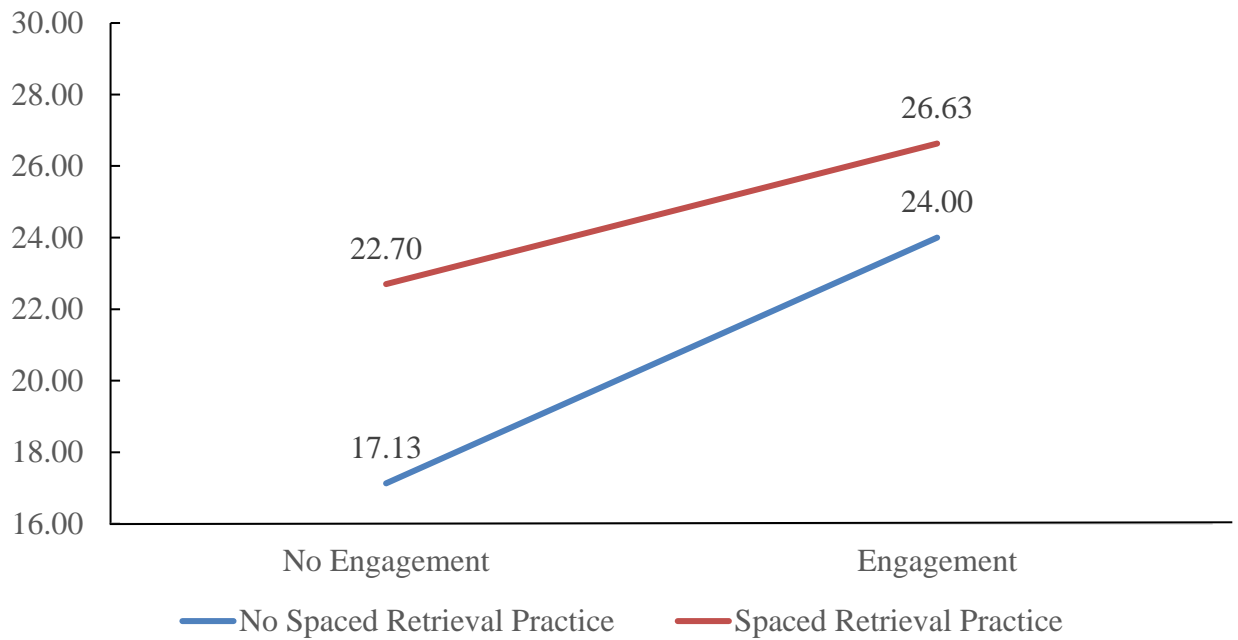
Multiple-choice mean scores were adjusted to remove the main effects of engagement level and use of spaced retrieval practice for further evaluation (Harwell, 1998; Rosnow & Rosenthal, 1989). Calculations from the adjustment suggest that the mean score for no engagement and no spaced retrieval practice decrease by 0.74, the mean score for no engagement and spaced retrieval practice increase by 0.73, the mean score for engagement and no spaced retrieval practice increase by 0.73 and the mean

score for engagement and spaced retrieval practice decrease by 0.74. Table 3 below

contains the adjusted mean scores, standard deviations and effect sizes.

Table 3

Adjusted Mean Scores on Multiple-Choice Examination for Significant Interaction

Adjusted Multiple-Choice Examination Scores

Engagement Level	Spaced Retrieval Practice	Group	n	M	SD	Cohen's d
No Engagement	No Spaced Retrieval Practice	1	30	16.39	5.06	1.40
	Spaced Retrieval Practice	2	30	23.43	5.10	
	Total		60	19.92	5.76	
Engagement	No Spaced Retrieval Practice	3	30	24.73	2.70	0.48
	Spaced Retrieval Practice	4	30	25.89	2.06	
	Total		60	25.32	2.73	
Total	No Spaced Retrieval Practice		60	20.57	5.31	
	Spaced Retrieval Practice		60	24.67	4.34	
	Total		120	22.62	5.25	
No Engagement	No Spaced Retrieval Practice	1	30	16.39	5.06	2.10
Engagement		3	30	24.73	2.70	
No Engagement	Spaced Retrieval Practice	2	30	23.43	5.10	0.63
Engagement		4	30	25.89	2.06	

For those groups with significantly different mean scores, a Cohen's *d* was

calculated to determine the magnitude of the difference using the adjusted mean scores.

The Cohen's *d* for no engagement/ no spaced retrieval practice (control group) and no

engagement/ spaced retrieval practice was 1.4, a large effect. The Cohen's *d* for no

engagement/ no spaced retrieval practice control group) and engagement/ no spaced retrieval practice was 2.10, or a large effect. The Cohen's *d* for no engagement/ spaced retrieval practice and engagement/ spaced retrieval practice was 0.63, or a moderate effect. The Cohen's *d* for engagement/ spaced retrieval practice and engagement/ no spaced retrieval practice was 0.48, or a moderate effect.

Dentoform Assessment Scores

As a review, lower scores on the dentoform assessment represented a more accurate evaluation of the dentoform compared to the mean score of the seven calibrated dental faculty. Higher scores then represented the less accuracy in retaining, retrieving and applying core content needed for self-assessment. As reported in Table 4, group 1 (control group: no engagement and no spaced retrieval practice; $n = 30$) reported mean score of $M = 32.33$ ($SD = 3.10$), which was the highest overall mean score of the groups. Group 2 (no engagement and spaced retrieval practice; $n = 30$) scored a group mean score of $M = 30.93$ ($SD = 3.62$). Group 3 (engagement and no spaced retrieval practice; $n = 30$) scored a group mean score of $M = 27.83$ ($SD = 3.23$). Group 4 (engagement and spaced retrieval practice; $n = 30$) had a mean score of $M = 25.87$ ($SD = 3.38$), which was the lowest overall mean score across groups. In addition, the mean score for all students that received no engagement was 31.63 ($SD = 3.39$) compared to 26.85 ($SD = 3.39$) for students that received engagement. Also, all students that received no spaced retrieval practice had a mean score of $M = 30.08$ ($SD = 3.85$; $n = 60$) compared to students that received spaced retrieval practice with a mean score of $M = 28.40$ ($SD = 4.31$; $n = 60$), whereas the mean across all students ($n = 120$) was 29.24 *($SD = 4.16$)*.

Table 4

Descriptive Statistics for Simulated Hands-On Dentoform Assessment

Simulated Hands-on Dentoform Assessment Scores

Engagement Level	Use of Spaced Retrieval Practice	Group	*n*	*M*	*SD*
No Engagement	No Spaced Retrieval Practice	1	30	32.33	3.06
	Spaced Retrieval Practice	2	30	30.93	3.62
	Total		60	31.63	3.39
Engagement	No Spaced Retrieval Practice	3	30	27.83	3.32
	Spaced Retrieval Practice	4	30	25.87	2.06
	Total		60	26.85	3.42
Total	No Spaced Retrieval Practice		60	30.08	3.85
	Spaced Retrieval Practice		60	28.40	4.31
	Total		120	29.24	4.16

Model Assumptions

To evaluate the assumption of homogeneity of variance, a Levene's Test of Equality of Variance was performed to test the null hypothesis that error variance of the dentoform assessment scores were equal across groups. It was determined that this test was not significant, $p > 0.05$. The null hypothesis was rejected suggesting the error variance across groups were equal. To evaluate the assumption of normality mathematically, a Shapiro-Wilk test was performed to test the null hypothesis that the dentoform assessment scores were not normal distributed across all levels of the independent variables. The combination of no engagement and no spaced retrieval practice on the dentoform assessment scores was statistically significant at $p < 0.05$. The Q-Q plot of the data supported the Shapiro-Wilk test, and inspection of boxplots

indicated there were no outliers across groups on this outcome. Therefore, these assumptions were met, and the factorial ANOVA proceeded forward.

Analysis of Variance Testing

The main effect for factor A, engagement, was statistically significant, $F(1, 116)$ = 62.00, $p < .05$, indicating engagement was associated with improved dentoform scores. The main effect of engagement yielded a partial eta squared value of 0.348 suggesting 34.8% of the variance in the simulated hands-on assessment scores can be explained by level of engagement. Figure 6 indicates that the simulated hands-on assessment scores were significantly lower for engagement ($M = 26.85$, $SD = 3.42$) than for no engagement ($M = 31.63$, $SD = 3.39$). Students that were engaged scored on average 4.78 points lower than students not engaged. Cohen's *d* was 1.40 indicating a large effect size.

Figure 6

Overall Mean Scores of Engagement for Dentoform Assessment
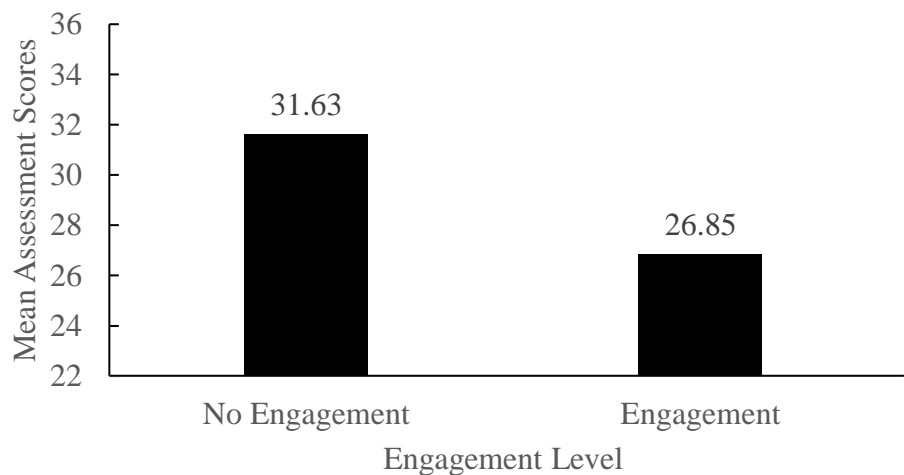
The main effect of spaced retrieval practice yielded an F ratio of $F(1, 116) = 7.68$, $p < .05$, indicating that the simulated hands-on assessment scores were significantly lower using spaced retrieval practice ($M = 28.40$, $SD = 4.31$) than not using spaced retrieval practice ($M = 30.10$, $SD = 3.85$). Therefore, the null hypothesis was rejected for this between subject's evaluation. Figure 7 shows students that received spaced retrieval practice scored on average 1.7 points lower than students not receiving spaced retrieval practice. The main effect of spaced retrieval practice yielded a partial eta squared value of 0.062 suggesting 6.20% of the variance in the simulated hands-on assessment scores can be explained by spaced retrieval practice. Cohen's d was 0.41 indicating a small effect size.

Figure 7

Overall Mean Scores of Spaced Retrieval Practice for Dentoform Assessment
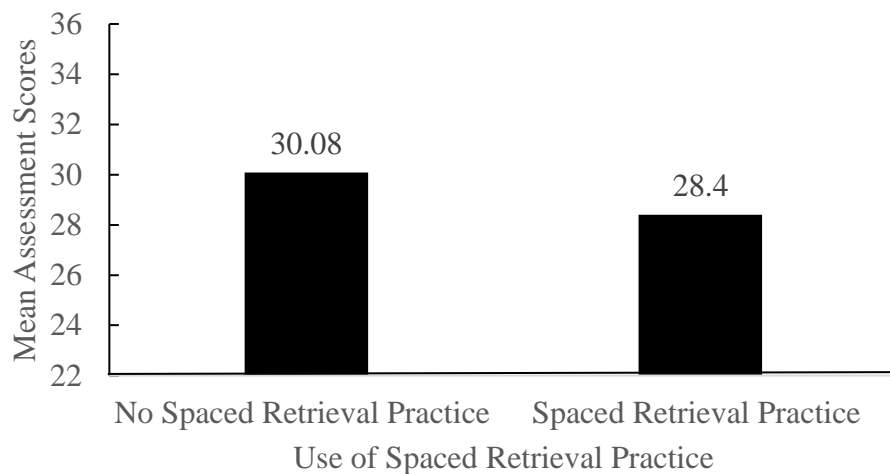
The interaction effect of engagement level and use of spaced retrieval practice was not statistically significant, $F(1, 116) = 0.218$, $p > .05$, failing to reject the null

hypothesis. Thus, the combination of engagement and spaced retrieval practice was not associated with improving the application of core content needed for D1 students to evaluate the hands on dentoform activity.

Student Self-Appraisal Confidence Level Scores

As a review, higher reported confidence scores represented more confidence in utilizing core content needed for self-assessment activities. Table 5 reports the descriptive statistics for the self-efficacy survey. As reported, All D1 dental students completed the post intervention self-appraisal confidence questionnaire ($N = 120$). Group 1 (no engagement and no spaced retrieval practice; $n = 30$) scored a group mean score of $M = 40.47$ ($SD = 3.66$), which was the lowest overall mean score of the groups. Group 2 (no engagement and spaced retrieval practice; $n = 30$) scored a group mean score of $M = 54.40$ ($SD = 4.90$). Group 3 (engagement and no spaced retrieval practice; $n = 30$) scored a group mean score of $M = 70.17$ ($SD = 4.10$). Group 4 (engagement and spaced retrieval practice; $n = 30$) scored a group mean score of $M = 85.73$ ($SD = 6.91$), which was the highest overall mean score of the groups. Total mean score for all students that received no engagement was 47.42 (SD = 8.23) compared ($n = 60; M = 47.42; SD = 8.23$) to students that received engagement ($n = 60; M = 77.95; SD = 9.66$). Additionally, all students that received no spaced retrieval practice had a mean score of 55.32 ($SD = 15.46$) ($n = 60$ compared to all students that received spaced retrieval practice ($n = 60; M = 70.10; SD = 16.88$). The grand mean for all groups was 62.69 (SD = 17.74) ($n = 120$).

Table 5

Descriptive Statistics for Self-Efficacy Survey

Self-Efficacy Confidence Scores

Engagement Level	Use of Spaced Retrieval Practice	Group	*n*	*M*	*SD*
No Engagement	No Spaced Retrieval Practice	1	30	40.47	3.66
	Spaced Retrieval Practice	2	30	54.50	4.90
	Total		60	47.42	8.23
Engagement	No Spaced Retrieval Practice	3	30	70.17	4.10
	Spaced Retrieval Practice	4	30	85.73	6.91
	Total		60	77.95	9.66
Total	No Spaced Retrieval Practice		60	55.32	15.46
	Spaced Retrieval Practice		60	70.10	16.88
	Total		120	62.69	17.74

Model Assumptions

To evaluate the assumption of homogeneity of variance, a Levene's Test of Equality of Variance was performed to test the null hypothesis that error variance of the self-appraisal confidence level scores were equal across groups. It was determined that this test was significant at $p < 0.05$. The null hypothesis was not rejected suggesting that the error variance of the self-appraisal confidence level scores were not equal across groups. Although the error variance was determined not to be equal across groups, the ANOVA evaluation proceeded. To evaluate the assumption of normality mathematically, a Shapiro-Wilk test was performed to test the null hypothesis that the self-appraisal scores were not normal distributed across all levels of the independent variables. The combination of no engagement and no spaced retrieval practice on the self-appraisal scores was statistically significant at $p < 0.05$. The null hypothesis was not rejected for

this evaluation suggesting the self-appraisal scores were not normally distributed. The Q-Q plot of the data supported the Shapiro-Wilk test. However, the boxplot suggested there were no outliers for this evaluation. The combination of no engagement and spaced retrieval practice on the dentoform assessment scores was statistically significant at $p < 0.05$. The Q-Q plot of the data supported the Shapiro-Wilk test. The boxplot suggested there were five outliers for this evaluation (cases 32, 37, 47, 57 and 62). The combination of engagement and no spaced retrieval practice on the self-appraisal scores was statistically significant at $p < 0.05$. However, the boxplots were not severely skewed, and the sample was representative of the population. With that, and the robustness of the methods, the ANOVA evaluation was continued forward.

The main effect of factor A, engagement, was statistically significant, $F(1, 116) = 1095.35$, $p < .05$, indicating that the self-appraisal assessment scores were significantly higher for engagement ($M = 77.95$, $SD = 9.66$) than for no engagement ($M = 47.43$, $SD = 8.23$). Therefore, the null hypothesis was rejected for this between subject's evaluation. Figure 8 below suggests students that were engaged scored on average 30.52 points higher than students not engaged. The main effect of engagement yielded a partial eta squared value of 0.904 suggesting 90.40% of the variance in the self-appraisal assessment scores can be explained by level of engagement, with Cohen's d of 3.40 indicating a large effect.

Figure 8

Overall Mean Scores of Engagement on the Self-Efficacy Survey
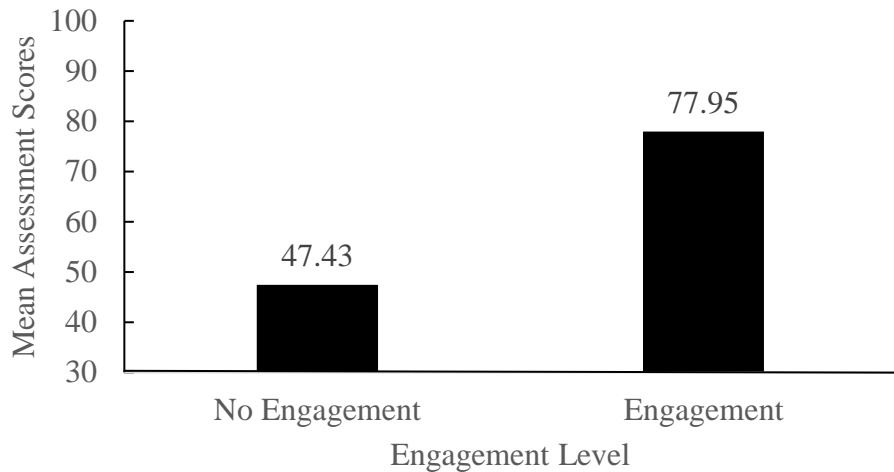
The main effect of spaced retrieval practice yielded an F ratio of $F(1, 116) = 7.68$, $p < .05$, indicating that the self-appraisal assessment scores were significantly higher using spaced retrieval practice ($M = 70.10$, $SD = 16.87$) than not using spaced retrieval practice ($M = 55.32$, $SD = 15.46$). Therefore, the null hypothesis was rejected for this between subject's evaluation. Figure 9 below suggest students that received spaced retrieval practice scored on average 15.38 points higher than students not receiving spaced retrieval practice. The main effect of spaced retrieval practice yielded a partial eta squared value of 0.688 suggesting 68.80% of the variance in the self-appraisal assessment scores can be explained by spaced retrieval practice. Cohen's d was 0.91 indicating a large effect.

Figure 9

Overall Mean Scores of Spaced Retrieval Practice on the Self-Efficacy Survey
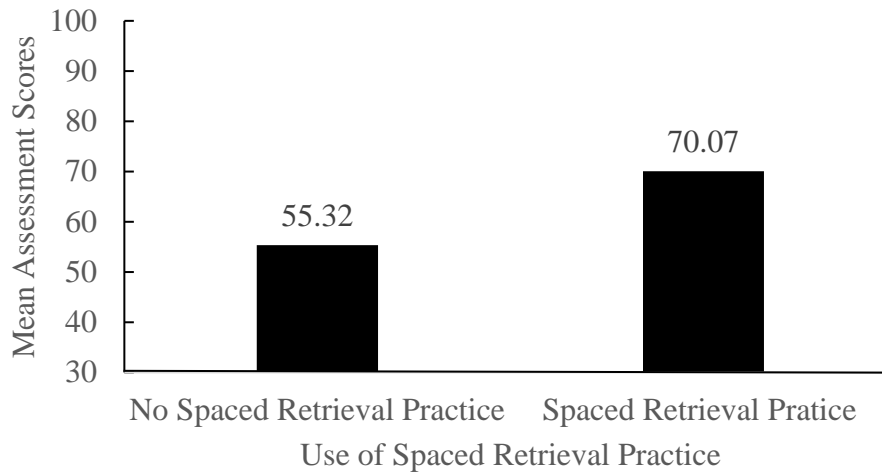
The interaction effect of engagement level and use of spaced retrieval practice was not statistically significant, $F(1, 116) = 0.784$, $p > .05$, failing to reject the null hypothesis. The results indicate that the combination of engagement and spaced retrieval practice did not result in significantly higher self-reported confidence scores.

The self-appraisal confidence questionnaire was subjected to psychometric analysis to evaluate the internal reliability of the instrument. The instrument consisted of a 10 item Likert scale questionnaire with higher scores representing higher self-reported confidence levels (0= not confident; 10= confident). Table 6 contains the descriptive statistics for the 10 question Likert scale self-efficacy confidence level questionnaire. Cronbach's alpha reported a high reliability coefficient, $\alpha = 0.99$, indicating the potential redundancy of items.

Table 6

Descriptive Statistics for Self-Efficacy Questionnaire

Scale Question	n	M	SD	Median	Minimum	Maximum
I am confident in my ability to recognize contraindications to local anesthesia.	120	6.05	1.90	6.00	3	10
I am confident in my ability to recognize dental caries on a digital bitewing radiograph.	120	6.53	1.93	7.00	3	10
I am confident in my ability to establish infection control barriers following CDC guidelines.	120	6.18	1.84	6.00	3	10
I am confident in my ability to self-assess the outline form dimensions of a class II preparation.	120	6.25	1.86	6.00	3	10
I am confident in my ability to self-assess the retention form dimensions of a class II preparation.	120	6.16	1.78	6.00	3	10
I am confident in my ability to self-assess the resistance form dimensions of a	120	6.38	1.79	7.00	3	10

class II
preparation.

I am confident in my ability to self-assess marginal ridge placement on a class II restoration.	120	6.27	1.81	7.00	3	10
I am confident in my ability to self-assess marginal adaptation on a class II restoration.	120	6.37	1.93	7.00	3	10
I am confident in my ability to self-assess proximal contact placement on a class II restoration.	120	6.27	1.73	6.00	3	10
I am confident in my ability to self-assess proximal contact strength on a class II restoration.	120	6.20	2.07	6.50	3	10

CHAPTER 5

DISCUSSION

As dental education seeks new and innovative instructional techniques to promote

students' attainment of clinical competencies, alternative techniques to the traditional,

passive lecture style instructional modality need to be investigated (CODA, 2019; Palatta

et al. 2017). In response, the purpose of this study was to evaluate the use of active

engagement and spaced retrieval practice as potential alternatives to traditional passive

instruction for learners acquiring self-assessment skills. Much of the current literature

supports active engagement of course material to reinforce core concepts, drive self-

directed learning and improve memory retention and retrieval of key learned information

(Carpenter et al., 2012; Michael, 2006; Morales, 2017). Along the same lines, spaced

retrieval practice has gained support in the current literature to improve short- and long-

term memory retention and retrieval of key learning objectives (Cepeda et al., 2006;

Mozer et al., 2009). However, most of the current literature on active engagement and

spaced retrieval practice have been situated within the K-12 and undergraduate college

levels (Freeman et al., 2014; Karpicke, 2009; Karpicke & Reodiger, 2008; Kuh,

O'Donnell & Schneider, 2017). Of particular interest in the study was how active

engagement and spaced retrieval practice together could promote professional

competencies at the graduate level on novice dental students leaning self-assessment

skills.

The results from this study were crucial for dental education because self-assessment skills are said to be the nucleus of self-directed learning and the key in promoting life-long learners (Chamber & LaBarre, 2014). Self-assessment is a crucial part of dental school professional competencies where students begin to critique their own work and modify behaviors to achieve desirable performance outcomes (CODA, 2019). Unfortunately, ULSD still struggles with dental students showing lack of knowledge in self-assessment skills too far into the curriculum using a traditional, passive instruction method (Metz et al., 2017). According to the most recent regional Consortium of Operative Dentistry Educators meeting, 90% of the twelve schools attending faced similar concerns of delayed student self-assessment capabilities. Therefore, careful consideration of innovative instruction and providing a richer learning environment for dental students that promotes metacognition (Logan, Castel, & Viehman, 2012), self-regulation (Gandomkar et al., 2016), and self-efficacy (Gist, Schwoerer, & Rosen, 1989) was needed. Furthermore, it will help ULSD fulfill the call from governing agencies to provide innovative instruction while achieving student professional competencies needed for a competent, beginning dental practitioner (CODA, 2019; Palatta et al., 2017).

The results from this study shed light on the inefficiencies of using a traditional lecture style while acquiring student self-assessment skills at the graduate healthcare level. Student self-assessment skills are supported by several relevant theoretical frameworks that immerse students in course content, allow essential experiences, identify deficiencies, reprogram actions and incorporate learned information into new experiences. These theoretical frameworks are not supported by a passive, traditional lecture style format. More specifically, a traditional lecture format does not engage

students in core course content and provides a passive, teacher-centered learning environment (Michael, 2006). In this study, students achieved significantly higher academic performance in retaining, retrieving and applying core course content using either active engagement or spaced retrieval practice compared to traditional lecture format. Additionally, students achieved significantly higher academic performance in retaining and retrieving core course content using both active engagement and spaced retrieval practice together. The addition of engagement alone yielded a larger effect size than the addition of spaced retrieval practice alone. With the significant interaction on the multiple-choice examination, adding engagement alone yielded a stronger effect than adding spaced retrieval practice alone. However, adding both engagement and spaced retrieval practice improved mean scores significantly with a large effect size. Lastly, students reported significantly higher confidence level scores in retaining, retrieving and applying core course content using either active engagement or spaced retrieval practice.

The results from this study support the current literature on student engagement and utilization of spaced retrieval practice in improving learning outcomes (Karpicke, 2009; Karpicke & Roediger, 2008; Kuh, O'Donnell, & Schneider, 2017; Michael, 2006; Morales, 2017). In agreement with this study, previous studies have shown that providing students engaging activities while learning core course concepts have improved academic performance scores (Armbruster et al., 2009; Freeman et al., 2014; Brydges et al., 2015). Also, once a student grasps information enough to retrieve it, additional retrieval of that information will increase the likelihood of long-term retention (Karpicke, 2009; Karpicke & Reodiger, 2008). Immersion of students into a self-controlled learning environment with real-time hands-on application and retrieval provides students with practical

application of key concepts (Armbruster et al., 2009; Freeman et al., 2014; Brydges et al., 2015). However, many of these academic improvements have been shown at the K-12 and undergraduate college levels leaving a gap for graduate level healthcare training (Freeman et al., 2014; Karpicke, 2009; Karpicke & Reodiger, 2008; Kuh, O'Donnell & Schneider, 2017). The results from this study are novel in that the use of these instructional methods has been largely unexplored at the graduate healthcare level with students learning how to perform self-assessment. Additionally, the interaction effect of evaluating both engagement and spaced retrieval practice together brought a novel evaluation to the current literature for further discussions.

The information gained from this research project will now be key in challenging the current curricular model used for hand-skills courses at ULSD, especially in the new COVID-19 environment. As ULSD strives to improve its curriculum during this extensive review process amidst a pandemic, this study provided empirical evidence that can now be utilized for critical decisions that aim to meet CODA directives, student performance outcomes and governmental limitations enforced facing a life-threating pandemic. Additionally, the empirical evidence from this study filled gaps in the literature on spaced retrieval practice, active learning engagement and their potential interaction during instruction. Previously, there were gaps in the education literature on using active learning in combination with spaced retrieval practice in the professional healthcare school environment. Lastly, the empirical evidence will help shape discussions on how to continue to provide the optimal learning environment for students to learn about self-assessment and its relationship to clinical competence and life-long learning.

The implications of these research findings are multifaceted in terms of dental accreditation, faculty development and student learning outcomes. In terms of dental accreditation, providing students with evidence-based instructional techniques and supporting data will allow successful progress towards learning self-assessment, reaching clinical competency and becoming life-long learners. Thereby reaching dental accreditation standards set for competent beginning dental professionals entering patient care. In terms of faculty development, further training will be needed to help faculty navigate the nuances of implementing active learning and spaced retrieval practice into their respective courses. As a department chair mentoring faculty, time allocation and resources will be crucial commodities in developing faculty annual work plans and professional development series. For most faculty in my department, transitioning passive lecture content into an engaging environment will need time and training by local experts. At ULSD, that will be the Delphi Center for Teaching and Learning that focus on training faculty in innovative instructional techniques and student learning outcomes. In terms of student learning outcomes, having students obtain a deeper understanding of self-assessment at the core of knowledge acquisition is crucial in obtaining self-corrective learning. It is the self-corrective process through self-assessment that students weave themselves into the theoretical frameworks that supports its foundation.

The results from this study provided further support for the theoretical frameworks used as a pillar to support the foundation of self-assessment. Students that were exposed to engagement of course material and utilized spaced retrieval practice better grasped the course material through experiential learning. Students gained a deeper understanding of the core concepts through experiences and application of key tenants

needed for self-assessment. This is the essence of the constructivist theory of learning (Duffy & Bednar, 1991). Students exposed to engagement and spaced retrieval practice were better able to gather, assimilate, retain and retrieve self-assessment core concepts. This is the essence of the cognitive theory of learning. (Sweller & Paas, 2017). Students that were exposed to engagement and spaced retrieval practice could better apply core concepts learned across similar but new contexts. This the essence of the metacognitive theory of learning. (Susser & McCabe, 2013). Students that were exposed to engagement and spaced retrieval practice recorded higher levels of self-reported confidence in applying key tenants learned about self-assessment. Students that are more confident have the tools needed to provide accurate self-assessment and application of key tenants. This is the essence of the self-efficacy theory of learning (Lisda & Harina, 2018). Overall, self-assessment is a complex construct that is supported by many educational, social and phycological theoretical frameworks. The results from study provided further evidence of their complex, supportive and collective roles in developing students foundational knowledge in learning self-assessment.

As with most research projects, there can be limitations to the interpretation of the data. A limitation in this study was capturing the true essence of self-efficacy and the use of newly developed confidence scale. Self-Efficacy is a deep construct that requires numerous iterations of scale development to produce a psychometrically reliable instrument. Although there was a main effect for both active engagement and use of spaced retrieval practice, many of the statistical assumptions for interpreting the factorial ANOVA were not met. The assumptions of homogeneity of variance, normal distribution and outlier scores were all violated in some way. These results suggest that further work

is needed to tease out the true construct of self-efficacy as it related to student self-reported confidence levels in applying learned information. Additionally, the high internal reliability of the survey suggests that there may have been some redundancy in the questions. However, the descriptive data did follow the pattern of performance outcomes suggesting that students exposed to active engagement and spaced retrieval practice were more confident. Future work is needed to further develop the self-efficacy instrument used in this study. The high scores suggest students may be overly estimating their perceived ability therefore the questions may need to dive deeper to more fully understand this construct.

Careful thought and consideration should be used when designing an experimental research project to ensure its validity in terms of interpretation and generalizability. Campbell and Stanley (2005), report several factors that need to be considered that could jeopardize the internal and external validity of this experimental research design. Internal validity was defined as the basic minimum without which any experiment is uninterpretable (Campbell & Stanley, 2005). External validity was defined as how generalizable the results are to the population (Campbell & Stanley, 2005). Therefore, it was important to relate sources of potential invalidity that should be considered and means to control them as confounding variables. Careful consideration was given to these potential sources of invalidity during the design of this research project and will be discussed in detail.

Sources of potential internal invalidity for this experimental research design could have been history, maturation, testing, instrumentation, regression, selection and mortality (Campbell & Stanley, 2005). History was controlled in this study by testing all

four treatment groups at the same time and in the same setting. Maturation and testing were controlled for this study in that they are manifested in all groups equally. Instrumentation was controlled by using the same assessment form and grading rubric for all treatment groups. Regression was controlled by randomization of the treatment groups resulting in similar regression across groups. Selection bias was controlled by randomization of participants into treatment groups. Mortality was controlled by having a short experiential design over six weeks. Consideration of these potential sources of internal validity were crucial in the overall evaluation of the results as it relates to the experimental design. Future research projects should use a similar research design to continue answering questions about how engagement and spaced retrieval practice improve student self-assessment skills.

Sources of potential external invalidity for this experimental research design could have been situational factors, sample features and selection bias (Campbell & Stanley, 2005). Situational factors were controlled to improve the generalizability of the results by utilizing a standard lecture auditorium that most dental schools possess. Additionally, utilizing a peer-reviewed and popular dental textbook for preparation and restoration guidelines that all dental schools have access to (Heymann, Swift, Ritter & Sturdevant, 2018). Sample features were controlled in that all dental admissions utilize similar criteria for admitting dental students (CODA, 2019) on a diverse population of candidates. Therefore, the results from this study translate well to all D1 dental students attending CODA approved dental schools in the United States. Selection bias was controlled by inviting all D1 dental students to participate in this study and randomization of group assignments.

As a result of the positive outcomes associated with student engagement and spaced retrieval practice on learning self-assessment skills, further evaluations are needed on a wider range of dental students and learner topics. One immediate research project should be how these cohort of students retain, retrieve and apply core concepts in evaluating their own hand-skill performance outcomes. The question still remains is that if students are engaged and use spaced retrieval practice gaining formative knowledge can they accurately evaluate and identify deficiencies through self-assessment evaluating their own work. Also, more work is needed to truly grasp the effects of active engagement and spaced retrieval practice on dental student learner outcomes in the basic sciences, clinical sciences and clinical professional competency evaluations. Future research should evaluate the potential synergistic effect of active engagement and spaced retrieval practice on student academic performance in many areas other than preclinical operative dentistry. Specifically, disciplines that still utilize a traditional, passive lecture format to present core course content where students are expected to evaluate performance outcomes.

Active engagement and spaced retrieval practice may hold the key to frontloading core dental school learning concepts to expedite student professional competencies in dental education. All areas in dental education with key core concepts, like self-assessment for competency, could benefit from both engagement and spaced retrieval practice instruction. These instructional techniques may help unlock foundational core knowledge for D1 dental students, not only in hand-skills courses, but in cultural competency awareness, behavioral sciences, critical thinking and professional ethics. All of these areas are crucial tenants in developing a well-rounded, and competent beginning

dental professionals. Unfortunately, all of these areas still provide students with core course content using a passive, teacher-centered approach lecture instructional method. Not surprising, all of these core content areas are CODA mandates needed for continued accreditation at the dental school. Therefore, it will be crucial to evaluate frontloading many core D1 courses using active engagement and spaced retrieval practice instructional techniques. With this comes a real need to review the current dental school curricular models and welcome conversations about more evidence-based instructional techniques in the D1 year. For now, the results from this study are promising in helping dental students learn the art of self-assessment through behavior modification and the importance of life-long learning. The true sense of clinical competence is for learners to recognize critical errors in their hand skill performance outcomes, modify identified deficiencies and improve future experiences.

As a result of this study, all research participants not receiving both engagement and spaced retrieval practice will be awarded the opportunity to do so. Before this happens, 12-week results will be collected using the multiple-choice examination and the simulated dentoform across all four groups. The 12-week data will be compared to the 4- and 6-week data presented in this project for knowledge retention, retrieval and application. An immediate follow-up study will be to re-examine the same cohort of students at six months to evaluate retention, retrieval and application of learned information for self-assessment skills. It is hypothesized that all students from each of the four groups will have similar scores on the multiple-choice examination and the dentoform assessment activity after receiving these instructional techniques. The results from this study has opened the door for conversations about how to use evidence-based

instructional methods to teach complex skills like self-assessment to novice dental students. There will be many questions resulting from this study to open avenues for numerous research projects in dental education. Especially, when self-assessment is so crucial to the overall development of hand skills modification and reprogramming of experiences to reach a desired clinical outcome, clinical competence and life-long learning.

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APPENDICES

Appendix A- Self-Assessment Form

GDOM 834/846: CLINICAL OPERATIVE EVALUATION AND COMPETENCY SHEET

Class II Resin Composite   Tooth #: _____   Student Name: _____   Patient ID #: _____

CATEGORY	COMMENTS	FACULTY SCORE			STUDENT SCORE		
Overall Experience							
Preparedness: Medical Hx. Reviewed, Vitals Recorded, etc. (Intellectual Autonomy)		3	2	0	3	2	0
Technical Competence (Delivery Tech.)		3	2	0	3	2	0
Clinical Judgment (Confidence in Reasoning)		3	2	0	3	2	0
Time Management (>2 hours = 0)		3	2	0	3	2	0
Professionalism (Intellectual Integrity and Empathy)		3	2	0	3	2	0
Biomedical Application		3	2	0	3	2	0
*Infection Control Violations		Yes			Yes		
*Self-Assessment		Yes			Yes		
Cavity Preparation							
Retention Form		3	2	0	3	2	0
Outline Form (includes broken contacts)		3	2	0	3	2	0
Resistance Form		3	2	0	3	2	0
*Inadequate Anesthesia		YES			YES		
*Inadequate Rubber Dam Isolation		YES			YES		
*Caries Remaining		YES			YES		
*Iatrogenic Pulp Exposure		YES			YES		
*Existing Restorative Material Remaining		YES			YES		
*Liner poorly placed or not Requested		YES			YES		
*Extensive Hard or Soft Tissue damage		YES			YES		
Restoration							
Anatomical Form		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= Superior, 2= acceptable, 0=unacceptable **AVERAGE**		/13			/13		

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Appendix B- Grading Rubric

Overall Experience

Overall Experience and Intellectual Traits				
Category	Description	3 (Superior)	2 (Acceptable)	0 (Unacceptable)
Intellectual Autonomy: Preparedness via review patients medical history and recorded vitals.	Student's ability to come prepared for the procedure.	Student is thoroughly prepared for the procedure proposed without faculty intervention (e.g., completed paperwork, acceptable radiographs, reviewed medical history, vitals recorded, and understands clinical materials)	Student is generally prepared for the procedure proposed. No more than two faculty intervention during patient care.	Student not prepared for the procedure proposed. Student required excessive (more than two) faculty interventions.
Technical Competence: Technical delivery of care.	Student's ability to apply operative concepts into clinical practice.	Student can apply operative concepts to patient care without faculty intervention.	Student can generally apply operative concepts to patient care. No more than two faculty intervention during patient care.	Student unable to apply operative concepts to patient care. Student required excessive (more than two) faculty interventions.
Confidence in Reasoning: Clinical judgment in caries diagnosis and removal	Student's ability to diagnose and treatment plan accordingly.	Student diagnosed patient correctly and has extensive knowledge of the patient without faculty intervention.	Student diagnosed patient correctly and is generally familiar with patient. No more than two faculty intervention during patient care.	Student misdiagnosed patient or is not familiar with patient. Student required excessive (more than two) faculty interventions.
Time Management	Student's ability to provide timely care for patients under local anesthesia.	Student completed the procedure < 1.5 hours.	Student completed the procedure from 1.5 to 2.0 hours	Student completed the procedure > 2.0 hours.
Professionalism: Intellectual integrity and empathy	Student's ability to communicate professionally with both faculty and patients.	Student prioritized professional communication with faculty and was empathetic towards patient.	Student generally able to effectively communicate with the faculty and patient. Student experienced lapses in empathy or respect.	Student lacked the ability to communicate with the faculty and patient. Student was not empathetic or respectful.
Biomedical Application	Student must be able to discuss material selection recalling basic science knowledge	Student could recall all knowledge during questioning without hesitation	Student could recall most knowledge during questioning	Student could recall some knowledge but is unsafe to treat patients
*Infection Control	Student's ability to provide universal precautions during patient care.	All infection control violations are considered critical errors. Either Yes or No		
*Self-Assessment	Student must be able to recall knowledge and application of the grading rubric for accurate self-assessment.	All poorly performed self-assessments are considered critical errors. Either Yes or No		

Cavity Preparation Principles

Cavity Preparation				
Category	Description	3 (Superior)	2 (Acceptable)	0 (Unacceptable)
Retention Form	Student demonstrates an understanding of preparation features to provide mechanical retention of final restoration.	Student demonstrates the ability to place necessary primary retentive features. • Proximal walls converge occlusally 6 degrees • B & L walls converge occlusally 6 degrees • Grooves placed B & L Proximal walls No faculty intervention during the procedure	Student demonstrates the ability to place necessary primary retentive features. • Proximal walls converge occlusally 3-5 degrees • B & L walls converge occlusally 3-5 degrees • Grooves placed B & L Proximal walls but modifications needed Faculty intervened two times during the procedures	Student cannot demonstrates the ability to place necessary primary retentive features. • Proximal walls converge occlusally 0 degrees or diverge • B & L walls converge occlusally 0 degrees or diverge • Grooves placed B & L Proximal walls but where excessive of not identifiable Faculty intervened > two times during the procedures
Outline Form	Student demonstrates an understanding of preserving anatomical structures, breaking contacts, and material selection.	Student demonstrates an ideal outline form (e.g., reflects material selection, breaks contacts, no damage to adjacent tooth, and removes caries & undermined enamel) without guidance. Faculty does not need to suggest modifications.	Student demonstrates an acceptable outline form (e.g., reflects material selection, breaks contacts, slight damage to adjacent tooth, removes caries, may have slightly undermined enamel). Close to ideal Faculty may need to suggest modifications.	Student cannot demonstrate an acceptable outline form. Excessive removal of tooth structure without requesting modifications (any wall) Wrong prep for material selected Reverse curve indicated but not used Extensive faculty guidance necessary
Resistance Form	Student demonstrates an understanding of preparation features to prevent fracture of tooth and/or restoration.	Student demonstrates ideal placement of primary resistance form (e.g., flat pulpal floor at 1.5-2.0mm deep, rounded axial-pulpal line angles, and maintaining anatomical ridges) without guidance Faculty does not need to suggest modifications.	Student demonstrates acceptable placement of primary resistance form with guidance (e.g., some irregularity to pulpal floor depth, invasion of anatomical ridges) Close to ideal Faculty may need to suggest modifications.	Student cannot demonstrate placement of primary resistance form. Minimal occlusal prep (enamel remaining) Excessive occlusal prep (no modifications requested) Rough floors/margins Sharp axial-pulpal line angle Extensive faculty guidance necessary.
*Inadequate Anesthesia	Student's ability to provide profound anesthesia during patient care.	All inadequate anesthesia violations are considered critical errors (≥ 4 cartridges of lidocaine w/ 1:100k epinephrine). Either Yes or No		
*Inadequate Rubber Dam Isolation	Student's ability to isolate the operating field during patient treatment.	All rubber dam violations are considered critical errors. Either Yes or No		
*Caries Remaining	Student's ability to identify and remove caries.	All carious tissue violations are considered critical errors. Either Yes or No		
*Iatrogenic Pulp Exposure	Student's ability to communicate preparation modifications from ideal	All unapproved pulp exposure violations are considered critical errors. Either Yes or No		
*Existing Restorative Material	Student's ability to remove all existing restorative materials during replacement procedures.	All existing restorative material violations are considered critical errors. Either Yes or No		
*Poorly Placed Lining Material	Student's ability to place pulpal protection when indicated	All poorly placed pulpal therapy violations are considered critical errors. Either Yes or No		
*Hard/Soft Tissue Damage	Student's ability to operate without damaging surrounding structures.	All extensive hard and soft tissue damage violations are considered critical errors. Either Yes or No		

Cavity Restoration Principles

Cavity Restoration

Category	Description	3 (Superior)	2 (Acceptable)	0 (Unacceptable)
Anatomical Form	Student demonstrates the ability to restore anatomical landmarks and occlusion	Student demonstrates the ability to place the ideal and/or appropriate anatomical form in the restoration (e.g., marginal ridges, primary grooves, cusp heights, and occlusion) without guidance Faculty does not need to suggest modifications.	Student generally demonstrates the ability to place the correct anatomical form in the restoration (e.g., marginal ridges may be slightly high or low, primary grooves may be slightly deep or shallow, cusp heights may be slightly over or undercontoured, and occlusion may be slightly light or heavy) Close to ideal Faculty may need to suggest modifications.	Student cannot demonstrate the acceptable placement of anatomical form in the restoration (e.g., lack of marginal ridges, lack of primary grooves, cusp heights decidedly under or over contoured, and faulty occlusion) Significant marginal ridge discrepancy Hypoocclusion (non-functional) Lacks groove system (flat) Restoration needs replacement Extensive faculty guidance necessary.
Embrasure Form	Student demonstrates the ability to restore embrasure spaces to ideal	Student demonstrates the ideal placement of embrasure form and understands its role in gingival health without guidance Faculty does not need to suggest modifications.	Student generally demonstrates acceptable replacement of embrasure form Faculty may need to suggest modifications.	Student cannot demonstrate the acceptable replacement of embrasure form Too open (over finished) Too closed (under finished) Restoration needs replacement Extensive faculty guidance necessary.
Proximal Contact	Student demonstrates the ability to restore the strength and proper placement of proximal contacts	Student demonstrates the ideal placement of interproximal contacts (e.g., strength, location, and length) without guidance Ideal contact (pops floss) Correct location Correct length Faculty does not need to suggest modifications.	Student generally demonstrates acceptable placement of interproximal contacts (e.g., strength, location, and length). Light contact (catches floss) Location slightly displaced Acceptable length Faculty may need to suggest modifications.	Student cannot demonstrate the acceptable placement of interproximal contacts. Open contact (*critical error) Excessive contact (floss unable to pass through contact) Restoration needs replacement Extensive faculty guidance necessary.
Marginal Integrity	Student demonstrates the ability to provide smooth transitions between restorative material and tooth structure	Student demonstrates the ability to achieve ideal cavosurface margins that are smooth and free of voids, flash, and overhangs without guidance Faculty does not need to suggest modifications.	Student generally demonstrates the ability to achieve acceptable cavosurface margins. Minimal flash (otherwise ideal) Slightly bulky margins on restoration. Faculty may need to suggest modifications.	Student cannot demonstrate the ability to achieve acceptable cavosurface margins. Voids on margin (*critical error) Excessive flash Excessive overhang (*critical error) Restoration needs replacement Extensive faculty guidance necessary.
*Open/Short Margin	Student's ability to provide smooth transitions between restorative material and tooth structure	All open, short or voided margin violations are considered critical errors. Either Yes or No		
*Open Proximal Contact	Student's ability to restore the strength and placement of proximal contacts	All open proximal contact violations are considered critical errors. Either Yes or No		
*Proximal Overhang	Student's ability to provide smooth transitions between restorative material and tooth structure	All interproximal overhang violations are considered critical errors. Either Yes or No		
*Hyperocclusion	Student's ability to restore anatomical landmarks and occlusion	All instances of hyperocclusion violations are considered critical errors. Either Yes or No		
*Hard/Soft Tissue Damage	Student's ability to finish restoration without damaging surrounding structures.	All extensive hard and soft tissue damage violations are considered critical errors. Either Yes or No		

Appendix C- CODA Standards

Standard 1	Institutional Effectiveness
Standard 2	Educational Programs
Standard 3	Faculty and Staff
Standard 4	Educational Support Services
Standard 5	Patient Care Service
Standard 6	Research Program

Standard 2- Educational Programs

Self-Assessment (2-11): 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.

Intent: Educational program should prepare students to assume responsibility for their own learning. The education program should teach students how to learn and apply evolving and new knowledge over a complete career as a health care professional. Lifelong learning skills include student assessment of learning needs.

Retrieved from https://www.ada.org/~/media/CODA/Files/pde.pdf?la=en

Domain 1: Critical Thinking and Lifelong Learning

1.1.   Graduates must be competent in the use of critical thinking and problem solving, including their use in the comprehensive care of patients, scientific inquiry and research
methodology. (2-10)

1.2.   <mark>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. (2-11)</mark>

1.3.   Graduates must be competent to access, critically appraise, apply, and communicate scientific and lay literature as it relates to providing evidence-based patient care. (2-22)

Domain 2: Biomedical Sciences

2.1.   Graduates must be competent in the application of biomedical science knowledge in the delivery of patient care. (2-15)

Domain 3: Ethics and Professionalism

3.1.   Graduates must be competent in the application of the principles of ethical decision-making and professional responsibility. (2-21)

Domain 4: Health Care Communication and Cultural Sensitivity

4.1.   Graduates must be competent in the application of fundamental principles of behavioral sciences, incorporating patient values as they pertain to patient-centered promotion, improvement, and maintenance of oral health. (2-16, 5-2)

4.2.   Graduates must be competent in managing a diverse patient population and have the interpersonal and communication skills to function successfully in a multicultural work environment. (2-17)

Domain 5: Practice Management and Health Care Systems

Graduates must be competent in:

5.1.   Applying legal and regulatory concepts related to the provision and/or support of oral health care services. (2-18)

5.2.   Applying the basic principles and philosophies of practice management, models of oral health care delivery, and how to function successfully as the leader of the oral health care team. (2-19)

5.3.   Communicating and collaborating with other members of the health care team to facilitate the provision of health care. (2-20)

Domain 6: Patient Care

Graduates must demonstrate competence in providing oral health care within the scope of general dentistry for pediatric, adult, and geriatric patients (2-23), including:

A. Assessment, Diagnosis, and Treatment Planning

6.1. Patient assessment, diagnosis, comprehensive treatment planning, prognosis, and informed consent. (2-24a)

6.2. Screening and risk assessment for head and neck cancer. (2-24b)

6.3. Recognizing the complexity of patient treatment and identifying when referral is indicated. (2-24c)

6.4. Assessing the treatment needs of special needs patients. (2-25)

B. Health Promotion and Disease Management

6.5. Assess and identify oral health risk factors to determine a health promotion and disease prevention plan. (2-24d)

6.6. Evaluation of outcomes of treatment, retrieval strategies, and prognosis. (2-24o)

6.7. Local anesthesia, and pain and anxiety control, including consideration of the impact of prescribing practices and substance use disorder. (2-24e)

6.8. Restoration of teeth. (2-24f)

6.9. Communicating and managing dental laboratory procedures in support of patient care. (2-24g)

6.10. Replacement of teeth including fixed, removable and dental implant prosthodontic therapies. (2-24h)

6.11. Complete a periodontal evaluation, diagnosis, and non-surgical treatment of mild to moderate forms of periodontal disease; appropriately refer advanced periodontal disease. (2-24i)

6.12. Complete an endodontic evaluation, diagnosis, and treatment of uncomplicated endodontic cases and appropriately refer complex care. (2-24j)

6.13. Diagnose, identify, and manage oral mucosal and osseous disorders. (2-24k)

6.14. Complete a surgical evaluation, assessment, and treatment of uncomplicated hard and soft tissue oral surgical cases. (2-24l)

6.15. Prevent, recognize, and manage dental emergencies. (2-24m)

6.16. Identify and manage malocclusion to include space management. (2-24n)

6.17. Prevent, recognize, and manage common medical emergencies. (5-6)

CURRICULUM VITAE

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EDUCATION: **PhD**- Doctor of Philosophy in Educational Leadership, Evaluation
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University of Louisville, Louisville, Kentucky
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MS- Master of Science in Clinical Research
Indiana University/ Purdue University, Indianapolis, Indiana
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MSD- Master of Science in Dentistry
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DMD- Doctor of Dental Medicine
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BA- Biology
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PUBLICATIONS:

1. Metz CJ, Ballard E, and **Metz MJ**. The stress of success: An online module to
help first-year dental students cope with the Impostor Phenomenon. *J Dent Educ*.
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2. Metz CJ, Ballard E, and **Metz MJ**. (2019) An Online Module to Help Students
Cope with Impostor Thoughts. Life Science Teaching Resource Community

https://www.lifescitrc.org/resource.cfm?submissionID=11955 September 4, 2019.

3. Metz CJ, Downes S, **Metz MJ:** (2018) The in's and out's of science outreach: assessment of an engaging new program. *Adv Physiol Educ* 42(3): 487-492, 2018; doi.org/10.1152/advan.00085.2018

4. Metz CJ, **Metz MJ**. (2018) An online module to understand body fluid status in clinical cases. *MedEdPORTAL*. 2018;14:10719. https://doi.org/10.15766/mep_2374-8265.10719

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6. Durski M, **Metz M**, Crim G, Hass S, Mazur R, Vieira S (2018). Effect of Chlorhexidine Treatment Prior to Fiber Post Cementation on Long-Term Resin Cement Bond Strength. *Oper Dent.* 2018 Mar/Apr;43(2):E72-E80.

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9. Downes SE, **Metz MJ**, Metz CJ: (2017) A Novel Oral Health Outreach Activity for Elementary Grade Students. LifeSciTRC Publications; (2017). Available from: https://www.lifescitrc.org/resource.cfm?submissionID=11301

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13. **Metz MJ**, Durski MT, Chou CC, Crim GA, Harris BT, Lin WS. (2016) Microleakage of Lithium Disilicate Crown Margins Finished on Direct Restorative Materials. *Oper Dent*. Sep-Oct;41(5):552-562.

14. **Metz MJ**, Metz CJ, Durski MT, Aiken SA, Mayfield TG, Lin WS. (2016) A Training Program Using an Audience Response System to Calibrate Dental Faculty Assessing Student Clinical Competence. *J Dent Educ*. 80(9), 1109-1118.

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maxillary rehabilitation: A senior dental student clinical report. *J Prosthet Dent, 113*(4), 282-288.

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25. **Metz MJ**, Miller CJ, Lin WS, Abdel-Azim T, Zandinejad A, Crim GA. (2015). Dental student perception and assessment of their clinical knowledge in educating patients about preventive dentistry. *Eur J Dent Educ, 19*(2), 81-86.

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31. **Metz MJ**, Abdel-Azim T, Miller CJ, Lin WS, ZandiNejad A, Oliveira GM, Morton D. (2014). Implementation of a laboratory quality assurance program: the Louisville experience. *J Dent Educ*. 78(2), 195-205.

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Research Awards:

Sept. 2017   **Ruth Greenberg Award in Medical Education Research, 1ˢᵗ Place. Research Louisville 2017.**
Metz CJ, Metz MJ: Clinical Scenario Videos Improve D.M.D Students' Perception of the Basic Sciences and
Ability to Apply Content Knowledge. Abstract ID: F-15

Sept. 2017   **Ruth Greenberg Award in Medical Education Research, 2nd Place. Research Louisville 2017.**
Metz MJ, Metz CJ: A Training Program Using an Audience Response System to Calibrate Dental Faculty Assessing Student Clinical Competence. Abstract ID: F-16

Jan. 2016   **Top 10 ADEA Journal of Dental Education (JDE) articles of 2015, as selected by JDE Editor Dr. Nadeem Karimbux.**
Cynthia Jayne Miller and Michael James Metz. Can Clinical Scenario Videos Improve Dental Students' Perceptions of the Basic Sciences and Ability to Apply Content Knowledge? *J Dent Educ* 2015 79:1452–1460.

Oct. 2015   **Ruth Greenberg Award in Medical Education Research, 2nd Place. Research Louisville 2015.**
Metz, M. J., Miller, C. J., Lin, W. S: (2015). Dental student perception and assessment of their clinical knowledge in educating patients about preventive dentistry. October 30, 2015. Louisville, Kentucky. Abstract ID: F-20.

Mar. 2015   **The International Association of Dental Research. Ira Hill (Student) Michael Metz (Mentor).**
Chosen by Dr. Don Demuth (Associate Dean of Research) to submit an abstract for 2015 National IADR in Boston, MA. "Compressive Strength of Pressed Lithium Disilicate Crowns Supported by Various Core Materials: An in vitro Evaluation." Accepted poster presentation.

Oct. 2014   **The National Hinman Student Research Symposium. Tom Czechura (Student) Michael Metz (Mentor).**
Chosen by Dr. Don Demuth (Associate Dean of Research) to submit an abstract for 2014 National Conference in Memphis, TN. "Factors associated with the longevity of dental implants placed at the University of Louisville School of Dentistry: A retrospective records review from 2008-2013." Accepted Oral Presentation.

Sept. 2014   **Ruth Greenberg Award in Medical Education Research, 2nd Place. Research Louisville 2014.**
Metz MJ, Miller CJ, Lin WS, Zandinejad A: Implementation of a Laboratory Quality Assurance Program: The Louisville Experience. September 18, 2014. Louisville, Kentucky. Faculty Poster Submission F-17.

Apr. 2007   **Wm. Wrigley Jr. Company Graduate Student Award. Indiana University School of Dentistry's 15th Annual Research Day.**

Sponsored by the IADR/AADR. Metz MJ, Cochran MA, and Matis BD: Clinical evaluations of 15% carbamide peroxide on the surface microhardness and shear bond strength of human enamel.

Grants Awarded:

Title: An exploratory study of Burnout, Well-Being and Flourishing in U.S. dental students, faculty and community-based practitioners.
Mechanism: **ULSD Faculty Research Grant**
P.I. – **Beacham, A**. Co-Investigator – **Metz, M.**
Direct Funding: $2500.00
Dates: June 2020 – August 2021

Title: Marginal Staining between Pressed Lithium Disilicate Ceramic Crowns and Direct Restorative Materials by Various Fluids: a Microleakage Study.
Mechanism: **ULSD Faculty Research Grant**
P.I. – **Metz M**. Co-Investigator – **Jestel, S**
Direct Funding: $2370.00
Dates: June 2017 – August 2018

Title: Establishing a Science Outreach Program for Under-Represented Students in West Louisville
Mechanism: **The University of Louisville School of Dentistry Community Outreach Support**
P.I. – **Metz M**. Co-Investigator – **Metz, C**
Direct Funding: $10,000.00
Dates: June 2015 – August 2016

Title: Establishing a Science Outreach Program for Under-Represented Students in West Louisville
Mechanism: **The University of Louisville School of Medicine Internal Basic Grant Award**
P.I. – **Metz C**. Co-Investigator – **Metz, M; Immekus, C**
Direct Funding: $25,000.00
Dates: June 2015 – August 2016

Title: Establishing a Science Outreach Program for Under-Represented Students in West Louisville
Mechanism: **The University of Louisville School of Medicine Internal Basic Grant Award**
P.I. – **Metz C**. Co-Investigator – **Metz, M; Immekus, C**
Direct Funding: $25,000.00
Dates: June 2015 – August 2016

Title: Exploring Community Outreach in Kentucky: Oral Health Care Literacy Disparities in Louisville's West End.

Mechanism: **The University of Louisville Department of Physiology and Biophysics Community Outreach Support**
P.I. – **Metz C**. Co-Investigator – **Metz, M**
Direct Funding: $10,000.00
Dates: June 2014 – August 2015

2014-2016: Ivoclar Vivadent Corporation Grant: Gift-in-Kind donation of **$2632.65** worth of dental materials in support of dental materials research. The purpose of this donation was in support of research interests lacking in the published literature. Ivoclar Vivadent Sunshine Act Report, Report Confirmation Number: 30526511. Employee Reporting: Singhal, Shashikant. Reported Date: 1/20/2014.

- **Metz MJ,** Durski MT, Chou CC, Crim GA, Harris BT, Lin WS. (2016) Microleakage of Lithium Disilicate Crown Margins Finished on Direct Restorative Materials. Oper Dent. Sep-Oct;41(5):552-562.

2013-2014: **Ivoclar Vivadent Corporation Grant**: Gift-in-Kind donation. (2) Bluephase LED curing unit 100-240V (G2). Fair market value is $1275.00 a piece/ **$2550.00** for both. Serial numbers: 234703 and 234710. The purpose of the donation was to provide calibrated LED curing light sources for research projects. Ivoclar Vivadent Sunshine Act Report, Report Confirmation Number: CG44054480. Employee Reporting: Gilles, Christopher. Reported Date: 12/4/2013.