Using active learning techniques to improve oral health literacy among children in vulnerable populations.

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USING ACTIVE LEARNING TECHNIQUES TO IMPROVE ORAL HEALTH LITERACY AMONG CHILDREN IN VULNERABLE POPULATIONS

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DEDICATION

This thesis is dedicated to my parents

Dr. Kevin Downes and Mrs. Kimberley Downes

who have given me every encouragement and advantage in every realm of life.

AMDG

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ABSTRACT

USING ACTIVE LEARNING TECHNIQUES TO IMPROVE ORAL HEALTH LITERACY AMONG CHILDREN IN VULNERABLE POPULATIONS

Sarah Downes

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This thesis examines the effectiveness of an active learning approach in improving oral health literacy and attitude about science among at-risk students in the age range of third to sixth grades. This is done by designing and implementing a novel Oral Health Outreach module and video. Active learning components include engaging PowerPoint, oral hygiene discussion and demonstration, and finally a biofilm simulation, which utilizes glow-in-the-dark paint, dentoform models, and black lights that allow students to visualize the importance of plaque removal. Student comprehension of oral health concepts increased by an average of 52.4% on post-tests ($n=61$, $p<.05$, student's t-test). While there were no significant changes in student perception surveys, the instructor survey indicated both satisfaction with the program and noticeable positive changes in students' interest in the sciences. The results of the current project indicate that an active learning approach can improve student comprehension of oral health concepts.

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CHAPTER 1

INTRODUCTION

Oral health literacy among at risk children populations remains a significant problem in the United States (Baskaradoss, 2018; Horowitz & Kleinman, 2012; E. Miller, Lee, DeWalt, & Vann, 2010; Nye & Robinia, 2019; Patino et al., 2018). For this reason, many oral care providers have begun outreach initiatives to improve oral health literacy among vulnerable populations (Horowitz & Kleinman, 2012). One outreach initiative is to use engaging instructional techniques that immerse students in core oral health content (Hoeft, Barker, Shiboski, Pantoja-Guzman, & Hiatt, 2016). The current literature coins this student engagement “active learning” (C. J. Metz, Downes, & M. Metz, 2018). Active learning encompasses many different types of instructional techniques to include interactive video modules, simulation, interrupted lectures, think-pair-share and many others (Meyers, 1993). The ultimate goal in using active learning is to improve learners’ memory retention, recall and application of learned information (Lucas, Testman, Hoyland, Kimble, & Euler, 2013). Active learning gains theoretical support in the current literature through the lens of the cognitive theory of development and the constructivist theory of education (Fosnot, 2005; Newby, 2008; Piaget, 1936). The cognitive theory of development states that a child’s intelligence is not static but rather evolves in accordance with biological development and interaction with his surroundings (Piaget, 1936). The constructivist theory of education tells us that students gain mastery of new concepts through the synthesis of new ideas or concepts based on current and past information (Bruner, 1960). It is through the cognitive theory of development and the constructivist theory of education that this research project will seek to use active learning modules to engage at-risk students in learning and retaining oral health literacy information. The goal is that the use of modules and active learning techniques can improve short- and long-term retention of the learned information. Ultimately, if the information can be retained, recalled and applied to everyday hygiene schedules, then a shift in disease risk to the positive may result.

Theoretical Framework

Active learning is an approach to education that engages the student dynamically with information to allow intimate interaction with concepts aiding a high frequency of concept mastery (Freeman et al., 2014). The theoretical foundation for active learning can be found in the cognitive theories of Piaget (Piaget, 1936) and the constructivist theory of Bruner (Bruner, 1966). These two learning theories shed light on how students learn information, retain information and recall information through meaning and profound experiences (Confrey, 1990; Fosnot, 2005).

Piaget and Vygotsky were some of the earliest philosophers to lay the theoretical groundwork for later concepts like constructivism and active learning. Piaget was one of the most significant figures in the area of research in Developmental Psychology and its understanding of the cognitive process in humans throughout different ages (Cherry, 2019). Piaget's theory parses cognitive development of children into four stages: sensorimotor, pre-operational, concrete operational and formal operational. These sequential stages mark an individual's progress from understanding time and space to more advanced processes of abstract thinking and complex problem solving (Gauvain, 2009). Piaget advocated a "cooperative" and "autonomous" adult-child relationship especially in education (Piaget, 1965). He envisioned a relationship based on mutual respect, understanding, and cooperation instead of coercion (Piaget, 1965, 1971). He expressed that only through ceasing needless authority from the adult can a child be free to develop thought that is independent, creative, and moral. These tenets ground constructivism in the principle that coercion should be diminished in education as the pace of learning is centered on the individual student (Fosnot, 2005). Vygotsky is another educational theorist. He believed that scientific information cannot be originated within a child but rather it imposes logic on a child, working its way "down," while spontaneous realizations encouraged by Piaget work their way "up" (Fosnot, 2005). He described this meeting place between spontaneous concepts and the "systematicity and logic of adult reason" as the "zone of proximal development" (Fosnot, 2005; Kozulin, 1986). Vygotsky also introduced the foundation for Bruner's term "scaffolding," where the teacher provides "support points" in the learning process until independence can be achieved (Korepanova, 2009). Piaget's and Vygotsky's ideas provided the groundwork for further educational philosophies to develop.

Bruner expanded the ideas of philosophers like Piaget and Vygotsky to develop the constructivist theory of education. Bruner's theory of constructivism states that students can essentially learn any concept as long as it relates to or builds on what they already know and that learning is an active process on the part of the student. His theory of education addresses four main features of the learning process: the proclivity of a student to learn, the modes in which a concept can be restructured to allow the optimum ease of learning, the optimum sequencing of material, and the types and regulations of rewards and punishments (Bruner, 1966). In a concept he calls "scaffolding," students can use the knowledge of a teacher to access expansion and more-detailed steps in conceptual growth (Bruner, 1986). Bruner's theory was revolutionary and was influenced by concepts introduced by previous educational philosophers.

Bruner's constructivist theory is supported by many studies. One book outlines several case studies that implement, evaluate, and ultimately support the design of a constructivist classroom curriculum (Wilson, 1996). A 2016 study found that students enrolled in constructivist based learning environments for more time (t_1= two years) experienced "higher adjusted mean reading scores" on a standardized test than did students enrolled for less time (t_2=1year.) This study supports and emphasizes the positive effect a constructivist approach can have on student success (Harkness, 2016). The largest study to compare constructivist and non-constructivist styles of teaching was performed in 1997 by Pfannenstiel. He found that

> students whose teachers employ pedagogy based on constructivism attain higher levels of achievement than do students whose teachers use practices rooted in traditional beliefs about learning. Students in traditional classrooms do not outperform students in constructivist classrooms on any measure. . . . The extent to which the learning environment is teacher-directed is the single best negative predictor of standardized mathematics and language achievement. (Pfannenstiel, 1997)

In this study, students with constructivist classrooms performed significantly better than their traditional-classroom counterparts in tests of mathematics, language, classification, writing, reading, and social behavior (Pfannenstiel, 1997). These studies lend substantial support to and validation of the constructivist theory upon which active learning approaches are built.

Problem Statement

It is imperative that we explore the efficacy of active learning as applied to basic oral health concepts. Oral health literacy is a problem for much of Kentucky, America, and the world, as it is reflected by poor oral health (Baskaradoss, 2018). In 2016, a study that sampled over 2,000 students throughout five regions of Kentucky found that 37% of third- and sixth- graders examined showed untreated tooth decay ("Making Smiles Happen," 2017). This percentage has increased since 2001 when this population was measured at 31% ("Making Smiles Happen," 2017). In the state of Kentucky, between 2001 and 2016, the percentage of third- and sixth- graders needing urgent or early dental procedures increased from 32%-49% ("Making Smiles Happen," 2017). A study between 2011 and 2014 found that 17.5% of 5 to 19- year-old children in the United States had untreated dental caries ("Oral Health and Disease," 2017). About 91% of U.S. adults aged 20-64 had dental caries in permanent teeth according to the CDC in 2012 (Dye, Thornton-Evans, Li, & Iafolla, 2015). 17.5% of adults 65 and older, between 2011-2014, were edentulous ("Quickstats: Prevalence of Edentualism in Adults Aged ≥65 Years," 2011-2014). The Global Burden of Disease Study 2016 showed that oral diseases affect approximately half of the world's population (3.58 billion people.) The most prevalent condition was shown to be dental caries in permanent teeth. This study estimates that, globally, 2.4 billion people suffer from caries of permanent teeth and 486 million children experience caries of primary teeth (Petersen, 2005; GBD 2016 Disease and

Injury Incidence and Prevalence Collaborators, 2017). 60-90% of school-age children experience dental caries globally (Petersen, Bourgeois, Ogawa, Estupinan-Day, & Ndiaye, 2005). Data like these show a need for improvement in Kentucky, America, and the world as a whole.

Purpose of the Study

According to the current literature, poor oral health directly correlates with low oral health literacy (Baskaradoss, 2018). 16.9% of children in the U.S. ages 5-19 had untreated dental caries in a national survey taken 2013-2016, duly reflecting the current disparity in oral health literacy in youth ("Oral and Dental Health," 2017). However, active learning has successfully been shown to increase retention and recall of learned information. There exists a gap in the current literature as to whether active learning through the use of active learning modules and simulation could improve retention, recall and application of oral hygiene content. Therefore, the purpose of this study is to evaluate the use of active learning modules and simulation activities to improve at-risk student's short-term retention and recall of learned information. The information gained from this evaluation will help fill the gap in the current literature and provide a foundation in moving forward with reducing caries incidence plaguing at-risk populations.

Significance

This data collection is imperative to determining, understanding, and validating the usefulness of an active learning approach to improve oral health literacy among vulnerable pediatric populations. If the data collected indicates marked improvement in oral health literacy and comprehension, the implications may be extensive. For instance, increased comprehension may correlate to a direct improvement in daily hygiene habits over a lifetime. It may also result in increased parental and familial oral health practices as students can pass on their knowledge to those in their immediate circle. Furthermore, if there is an improvement in attitude toward the sciences, this exercise may facilitate an increase in successful education in STEM subjects and ultimately an openness toward careers in STEM among the disadvantaged. Additionally, should this research prove this approach to be a positive experience, it may encourage further experimentation and implementation of the active learning approach throughout ages, grades, and subjects.

Research Question

From gaps in the current literature on active learning and poor oral health literacy in vulnerable populations, the following research question was developed: Can the use of active learning modules and hands-on simulation improve memory retention and recall of learned information regarding oral health care literacy?

Research Hypothesis

It is hypothesized that utilizing active learning modules and hands on simulation will improve memory retention and recall of oral health literacy information and increase interest in science.

Definitions

Active Learning, according to Bonwell and Eison, is defined as "a method of learning in which students are actively or experientially involved in the learning process and where there are different levels of active learning, depending on student involvement" (Barnes, 1989). Active learning is an umbrella term that includes a variety of techniques including games, learning by teaching, classroom discussions, hands-on activities and many more. A few techniques employed in this study are simulation, classroom discussion, and interactive PowerPoint.

Simulation is an active learning technique used when trying to study a system where the real system cannot be implemented, because it may not be available, or it may be hazardous or unacceptable to employ, or it may not have been invented (Sokolowski, 2009). This study uses this technique to study and interact with biofilm in a safe, predictable, and accurate way.

Video modules are one method of employing active learning technique that is favorable because most students enjoy watching movies. Video is a medium that helps students understand a concept in another format than simple presentation (McKinney, 2010). The video created in this study poses relevant questions throughout to increase student engagement by highlighting key concepts on which to focus.

Cognition is defined as " the action or faculty of knowing taken in its widest sense, including sensation, perception, conception" ("cognition," 2020). This study provides multiple formats to introduce the concept of biofilm including sensory, experience, thought, and discussion to increase the likelihood of cognition.

The constructivist theory of education is an educational theory which holds that learning is an active process of constructing information into concepts rather than passively absorbing them and that it is the instructor's job to encourage independence and engagement while implementing an instructional scaffolding, which is an individualized support system progressively removed as concepts become mastered (Seifert, 2009; Cooper, 1993; Newby, 1993). Through this theory, the classroom session designed for this study engages students in an active way in each step that begins with close guidance through introduction and questioning and ends with independence and full engagement on the students' part by way of simulation.

Oral Health Disparity is a term that describes a disproportionate burden or risk of disease, disability, and ill health of the oral cavity on a particular population or group (Patrick et al., 2006). This study seeks to contribute to the amelioration of oral health disparities across the globe by designing, testing, and validating an active learning approach to oral health education.

Summary

In summary, poor oral health literacy and caries incidence is plaguing at-risk pediatric populations locally, nationally and internationally ("Making Smiles Happen," 2017; Petersen et al., 2005; "Oral Health and Disease," 2017). Intervention through dynamic oral health literacy may hold the key in improving conceptual knowledge in oral health care. Interventions in knowledge through the use of active learning that engages the students to retain, recall and apply oral health concepts may be the turning point. Researchers must first bridge the gap in the current literature as to whether active learning with simulation, interactive PowerPoints, and modules can improve oral health literacy among at-risk populations. Therefore, the purpose of this study is to evaluate the use of active learning modules to engage an at-risk pediatric cohort. It is hoped that through the engagement of this cohort, improvements can be seen in the retention and recall of learned oral health concepts. Results from this study will provide a foundation for future educational research studies and help bridge the gap in the current literature.

CHAPTER 2

REVIEW OF LITERATURE

This literature review will introduce, explore, and expand on the two foundational concepts for the purpose of this study: oral health disparities and active learning. The concept of oral health disparities will first be introduced, examined, and explained and will be followed by active learning in general, active learning techniques and support from literature, and finally the theoretical framework that supports active learning.

Oral Health Disparities

Oral Health is an integral part of systemic health that is often discounted. According to the Surgeon General's report entitled "Oral Health in America," which is the first to dial in on oral health concerns entirely, there is "*a silent epidemic of dental and oral diseases … a burden of diseases that restricts activities..*" (U.S. Department of Health and Human Services, 2000). While efforts to ameliorate these oral health problems have been made, there are still large subpopulations that are underserved and vulnerable as they experience disproportionately lower levels of oral health quality as noted by Surgeon General Murthy (Murthy, 2016).

Oral health disparities are most prevalent in individuals with lower socioeconomic status and minority ethnic groups. Despite efforts in communities to improve oral health (e.g. sealant programs and water fluoridation), health disparities continue to perpetuate for minority children (e.g., African American, Native American, and Latino) in comparison to Caucasian children (Flores & Tomany-Korman, 2008). Trends in data show that the poverty line is a separator between higher and lower oral health. These trends are consistent across every age group. According to data collected in 2012 one in four children in the United States in the age groups of 3–5 and 6–9 years living in poverty had untreated dental caries (Dye, Li, & Thorton-Evans, 2012). In the age group of 13–15, dental sealants are more common among non-Hispanic white adolescents than in non-Hispanic black adolescents (56% vs 32%) (Dye et al., 2012). In the age group of 45–64, only 29% had a full set of permanent teeth (excluding third molars); this population includes 19% of Hispanic adults and 11% of non-Hispanic black adults and nearly 35% of non-Hispanic white adults (Dye et al., 2012). Over one-third of elder adults in the age group 65–74 living below the federal poverty level (34%) were edentulous, whereas only about one-eighth of older adults living above the poverty level (13%) were edentulous (Dye et al., 2012)

Efforts have been made to explain patterns in oral health disparities. Socioeconomic status (SES) has been shown to be linked with oral health quality in a direct relationship. In an attempt to explain the association between low SES and poor oral health, a study by Gupta et al. studied 495 individuals in India. The authors' findings are evidence that SES may affect the degrees of resources such as community support and sense of coherence, two factors that mediate stress and consequently may influence individual oral health outcomes. Individuals with higher levels of SES experience increased levels of social support and a stronger sense of coherence. Higher levels of these resources are associated with lower stress levels and improved oral health. Thus, the psychosocial pathway seems to play a role in oral health quality in relation to SES (Gupta, Robinson, Marya, & Baker, 2015).

Minority status has also been shown to be linked with oral health disparities. It is very difficult to separate minority status from SES in examining oral health disparities (Kaufman, Cooper, & McGee, 1997). Part of the reason for this is that, when minority status in combination with SES is examined, minorities experience a diminished return (Assari, 2018a, 2018b). In other words, when ethnic minorities experience high SES, they do not experience outcomes proportional to the resources that accompany SES that are observed in whites (Assari, 2018b; Phelan, Link, & Tehranifar, 2010). This means that minority status can still outweigh financial advantage.

When examining solutions to ameliorate global oral health disparities, education is a recurring theme. The World Health Organization lists education as one of its strategies in the prevention of oral health disease: "health promoting schools is critical to building comprehensive supporting environments to promote oral health" ("Oral Health," 2018). Education is very important, and perhaps the most time and energy should be invested into fine-tuning, if not transforming, education of youth. This principle is supported by Edelstein, a Professor of Health Policy and Management and Dentistry (in Community Health) at the Columbia University Medical Center:

> Although caries is a disease that manifests throughout the lifespan, prioritizing children is appropriate because caries is first established in early childhood and plays out across the lifetime. Current conceptual frameworks that need to be addressed include shifting from characterizing dental caries as a condition to a disease; from passive to active management; from static to dynamic understanding of pathogenesis; from treatment to management; and from dento-centricity to individual and family centricity (Edelstein, 2006)

Thus, the case for education of youth can be made. If Herbert Spencer, 19th century philosopher, was correct in stating that "the great aim of education is not knowledge but change," then it is plausible that oral health can be impacted, improved, and enhanced through education (Spencer, n.d.).

Active Learning in general and techniques in practice

Active learning is defined as an approach to education that engages the student dynamically with information to allow intimate interaction with concepts aiding a high frequency of concept mastery. A key philosophy integral to the mode of thinking is constructivism: that learning is an active process of constructing information into concepts rather than passively absorbing them (Cooper, 1993 ; Newby, 1993).

Listed are some specific constructivist tenets that are significant to any instructional design implementing an active learning approach:

> 1. An emphasis on the identification of the context in which the skills will be learned and subsequently applied [anchoring learning in meaningful contexts].
> 2. An emphasis on learner control and the capability of the learner to manipulate information [actively using what is learned].
> 3. The need for information to be presented in a variety of different ways [revisiting content at different times, in rearranged contexts, for different purposes, and from different conceptual perspectives].
> 4. Supporting the use of problem-solving skills that allow learners to go "beyond the information given." [developing pattern-recognition skills, presenting alternative ways of representing problems].
> 5. Assessment focused on transfer of knowledge and skills [presenting new problems and situations that differ from the conditions of the initial instruction]. (Newby, 2008)

Active learning strategies like simulation, games, flipped classroom, and quizzing are successful in practice. Several studies have sought to prove the efficacy of these methods, but in the words of one researcher and educator "there is no single definitive experiment to prove this, nor can there be given the nature of the phenomena at work, but the very multiplicity of sources of evidence makes the argument compelling" (Michael, 2006).The interest here is in the compelling argument for education through active learning in the sciences, for which the support can be found in the variety of realms it is applied.

Gaming is one active learning method that has been used to facilitate student engagement. One study outlines the variables necessary to be measured in order to support gaming as a component of pharmacy school curriculum. Outcomes detailed include "test scores, student confidence in knowledge and skills, and retention of knowledge and skills" (Sera & Wheeler, 2017). It has been shown that active learning with respect to information presented through games and social media affects course outcomes in a nursing pharmacology course. They found that participation in class social media correlated with higher grades while gaming did not. Students reported an appreciation for both methods stating that they increased enjoyment, lowered stress, and allowed immediate feedback on progress. This is support for active learning strategy of in-class participation using social media (Morales, 2017). A study involving nursing students showed that the technique of gaming is not only positively accepted by students but successfully allows coverage of a large volume of material with one exercise (Boctor, 2013). Literature supports the use of gaming according to student perception and efficiency in volume of material covered.

Simulation is another active learning approach that has been successfully implemented and evaluated by undergraduate, dental, pharmacy, nursing and medical schools. One dental school utilized this approach with "medication minutes," a case-based application of pharmacology used in a second year dental school course. This active learning exercise produced better short term and long term retention than basic science knowledge alone. This shows support for active learning techniques in long and short term retention (Persky, 2017). Active learning through simulation in clinical education is greatly useful. A study found that when 24 medical students on surgery rotation had to complete two clinical simulations, the group receiving a pre-simulation orientation experienced reduced anxiety and improved confidence and performance (Bommer et al., 2018). Another study put to the test a two-phase role play patient simulation for nursing students to practice clinical judgment. Participating students reported increased comprehension of course material as a consequence of involvement in the clinical simulation (Comer, 2005). Creighton nursing school has developed a patient scenario simulation that incorporates both skill acquisition and care management concepts (Hawkins, Todd, & Manz, 2008). High-fidelity patient simulation in pharmacology has been shown to support retention of knowledge, improve clinical judgment, and can help mold safe practitioners for clinical practice (Thompson & Bonnel, 2008). Advantages of combining lecture with simulation include an increase in students' active classroom engagement, concurrently sharing simulations with numerous learners, "modeling students' thinking in clinical situations, and connecting theory to practice" (Kalmakis, Cunningham, Lamoureux, & Ahmed, 2010). Further support for the success of simulation in active learning is a study featuring medical students in Beijing China which proved the effectiveness of simulation training models in assessing cervical dilation clinically. Students receiving the simulation models experienced improved accuracy and confidence in assessing cervical dilation clinically (Lin & Song, 2018). Simulation has been shown to be useful for many fields of medical study including bronchoscopy and obstetrics (Nilsson, Naur, Clementsen, & Konge, 2017; Partin, 2011). Simulation is thus effective in a variety of fields and settings.

Flipped classroom is another active learning technique that has been used in the teaching of science-based curricula. While this method has been shown to be effective for increasing student engagement, comprehension of material, and motivation on several accounts, it is not universally preferred by students. When a second year dental school class's pediatrics class was changed to a flipped classroom design, students took on the responsibility of teaching each other. This change resulted in students reporting heightened learning due to increased engagement in discussion. Both students and the course director were satisfied with the change. This study notes that the high satisfaction of the design implemented was dependent on access to online content and course materials and involvement of both students and faculty in developing a system that works harmoniously (Bohaty, Redford, & Gadbury-Amyot, 2016). The effectiveness of the flipped classroom in ophthalmology taught at the clerkship level was tested with 95 medical students in another study. The flipped group consisted of 48 students, while the traditional group was composed of 47. More students from the flipped group related increased motivation to learn, improved understanding of concepts, but did not prefer this method as it placed more of a burden and pressure to learn on them than the students in the traditional group. This study found that while it is not the easiest or most preferred method for student comprehension, it is an effective one (Tang et al., 2017). Learning assistants have been used in tangent with a flipped classroom design and have been shown to be particularly beneficial to underrepresented minority students (Sellami, Shaked, Laski, Eagan, & Sanders, 2017). Another study evaluated the student perception of flipped versus tradition, lecture-style classes and found that first year “millennial” medical students prefer traditional lecture over flipped design and ultimately prefer “choice, flexibility, efficiency, and the ability to control the pace of their learning” (Pettit, McCoy, & Kinney, 2017). Thus, flipped classroom design is effective, but not always the preference of students.

There is definite support for the benefits of an active learning approach in student comprehension at a wide range of grade levels. At Brigham and Women's Hospital gastroenterology program, an active learning curriculum was developed and substituted for traditional lecture format. With 15 participants, the GI fellows not only preferred the active learning format, but also the students and faculty perceived a greater ease in comprehension (Inra, Pelletier, Kumar, Barnes, & Shields, 2017). Another study found that the use of active learning strategies to restructure the undergraduate biology curriculum at a university produced a significant improvement of student-reported engagement and liking and improved academic performance (Armbruster, Patel, Johnson, & Weiss, 2009). Miller published a study in 2013 which found significant benefits from engaging lecture methods compared to traditional lectures (C. J. Miller, McNear, & M. Metz, 2013). Furthermore, according to the National Survey on Student Engagement, students experience increased comprehension and retention of information with increased hands-on activities and active learning strategies (Kuh, 2001). Active learning has been widely implemented in younger grades using Bruner’s constructivist theory (Pfannenstiel, 1997; Piaget, 1962). These studies validate and support the use and effectiveness of active learning strategies with a wide range of ages.

These studies and data show that active learning strategies are successful upon implementation in an array of settings, contexts, and ages. Gaming, simulation, and flipped classroom designs are a few modes that still require a great deal of study and refinement in order to maximize benefits for students. This study utilizes active learning strategies supported by literature, including simulation, discussion, and interactive PowerPoint, with the hope that similar increases in comprehension, retention, and attitude can be seen with at-risk students in the context of oral health education.

Theoretical Framework

The premise of this study is rooted in active learning concepts. The foundation and essence of active learning techniques are grounded in the constructivist theory of education and the cognitive theory of development. Every segment of the active learning-based classroom session in this study was designed to be a pure expression of active learning and the supporting theories. In this study, the educational philosophies of the cognitive theory of development and constructivism are embodied in a one-hour active learning classroom session.

Support from Bruner

One great mind to consult when approaching education is that of Jerome Bruner, a prominent American psychologist who made strides in educational philosophy in the 20th century. Bruner introduced the concept of "Constructivism," the theory that learning is a product of experience and of students interacting with their environment (Bruner, 1966). His theories on education largely influenced this study's modus operandi to introduce biofilm to children and the architecture of the curriculum design from many angles. In order to deliver an abstract concept like biofilm to the minds of young students, there is a need to combine theory, in the form of engaging lecture, demonstration by example to encourage mirroring of techniques (Shukla, 2012,) questioning to engage students in thought processes (Socratic Method), and simulation (constructivism/synthesis.) This is the optimum design for the aim, with a final activity that calls on the highest level of learning according to Bloom's Taxonomy: synthesis (Bloom, 1956).

In his book "*The Process of Education*,"Bruner (1960) states that:

> one starts somewhere- where the student *is*. And one starts whenever the student arrives to begin his career as a learner. It was in this spirit that I proposed that any subject could be taught to any child at any age in some form that is honest. (p. i.x.)

This study embodies Bruner's theory because the resources were designed to access students through a variety of platforms to meet different styles of learning. By approaching the subject through repetition and variety of methods, there is a higher chance of meeting each student where they are in the learning process. With this principle, it is possible to teach young students something as abstract as biofilm as long as one meets them where they are. In this case that range was addressed theoretically (with PowerPoint), visually (through demonstration,) and tangibly (simulation.)

Bruner (1966) also believed in flexibility of design for classroom structuring:

> If a curriculum is to be effective in the classroom it must contain different ways of activating children, different ways of presenting sequences, different opportunities for some children to skip parts while others work their way through, different ways of putting things. A curriculum, in short, must contain many tracks that lead to the same general goal. (p. 71)

This principle of Bruner is manifested in the courses designed for this study. The curriculum was designed to facilitate every mode of learning: through repetition in concept and variety in method, it seems to have been effective considering the improvement in post-test results.

Bruner (1960) also states that "grasping the structure of a subject is understanding it in a way that permits many other things to be related to it meaningfully. To learn structure, in short, is to learn how things are related" (p. 7). This principle is integral to the study's mission of teaching students the concept of biofilm so that it will serve as a platform to relate disease to the need for oral health habits.

In his book "Toward a Theory of Instructionism," Bruner (1966) states that "any idea or problem or body of knowledge can be presented in a form simple enough so that any particular learner can understand it in a recognizable form" (p. 44). This study embodies this thought in that it seeks to represent biofilm in its most simple sense and pure nature and then build connections from that foundation. "In short, the sequence in which a learner encounters materials within a domain of knowledge affects the difficulty he will have in achieving mastery" (p. 49). This statement by Bruner (1966) created the rationale for the order of the classroom design. This classroom session seeks to minimize the difficulty in learning by sequencing intentionally. By starting with thought, it provides a logical basis for demonstration, which provides guidance for action. (theory>demonstration>simulation.)

Support from Piaget: Cognitive Theory of Development

The cognitive theory of development states that a child's intelligence is not static but rather evolves in accordance with biological development and interaction with his surroundings (Piaget, 1936). According to Piaget, the developing mind advances through four stages of understanding in a consecutive and specific order. Each stage is defined by age ranges that coordinate with levels of cognitive abilities: the sensorimotor stage (birth to 2 years), the preoperational stage (ages 2 to 7), the concrete operational stage (ages 7 to 11), and the formal operational stage (ages 12 and older) (Piaget, 1972). The subjects of this study range from third grade (estimated age of 8 years old) to sixth grade (11 years of age.) Thus the entire population of this study exists in the concrete operational stage which is a prerequisite to the formal operational stage (Piaget, 1958). The concrete operational phase is seen by advances in rational thinking including conservation, classification and reversibility, all of which lead to logical reasoning (Piaget, 1947). Thus, this population of students have not yet arrived at the formal operational stage, which is characterized by the ability to think *abstractly* and their ability to think hypothetically (Berger, 2014; Piaget, 1947).

The subject of biofilm is an abstract concept to students of this age group in that it is intangible and invisible. This study aims to breach this developmental gap between concrete logic and abstract thought with a simulation of biofilm. This study strives to concretize the abstract and to root oral hygiene principles in a *visible* and *tangible* experience. Piaget's theory of cognitive development is actively interpreted and vivified in the classroom design.

The simulation of biofilm in combination with other active learning techniques like interactive PowerPoints and classroom discussion breach a major gap in literature as they concretize the abstract, bridge cognitive stages, and utilize constructivism by creating student-centered learning for oral hygiene instruction instead of parent-centered instruction. Comprehension percent increases within this study will serve as the factor determining effectiveness of the active learning approach in improving oral health literacy in at-risk populations.

Study Purpose

The purpose of this study is to use active learning principles rooted in Piaget's cognitive theory of development and Bruner's theory of constructivism to empower full understanding of the abstract concept of biofilm and demonstrate that these techniques are effective in practice in the ambition of improving oral health literacy with the long-term mission of eradicating oral health disparities (Baskaradoss, 2018; Bruner, 1966; Piaget, 1947).

Significance of Study

This study's significance is that it validates fundamental educational theories in the context of modern classrooms with the relevant and urgent subject of oral health education. It empowers teachers and students to apply active learning principles in an effective, dynamic, and powerful way that creates two-way engagement which translates into deep understanding and ultimately action (ideally over a lifetime). It introduces science in a sensational way that promotes positive perception of the field and fosters curiosity and exploration in young minds when approaching the unknown. While this study is specific to oral health education in at risk youth, it lends an additional body of evidence to the idea that active learning and student-centered engagement are proven routes to retention and comprehension in any context.

CHAPTER 3

METHODS

Sample Selection and Participants

This study features a sample of 61 students from the third, fifth, and sixth grade classrooms at the J Graham Brown School which is known for its diverse assortment of students and openness to educational innovations ("About Brown," 2019). Sample dispersion through grades is as follows: from the third grade classroom, n= 20, from the fifth grade classroom n=22, and from the sixth grade classroom, n=19.

Consent and Data Privacy

IRB exemption for this project was obtained from both the University of Louisville (#14.1095) and the Jefferson County Public School System.

Instructional Materials and Group Presentations

The architecture of the classroom session from start to finish includes: a brief introduction, a pre-test that measures comprehension and attitude toward science, an engaging biofilm PowerPoint presentation, oral hygiene discussion, biofilm simulation activity, post-test for comprehension and attitudes, and finally the distribution of goodie bags (Figure 1.) This sequence is vital as each step lays a foundation for the next. Theory from the PowerPoint gives credence to the strategies for oral hygiene instructions which acts as a premise for the biofilm simulation activity.

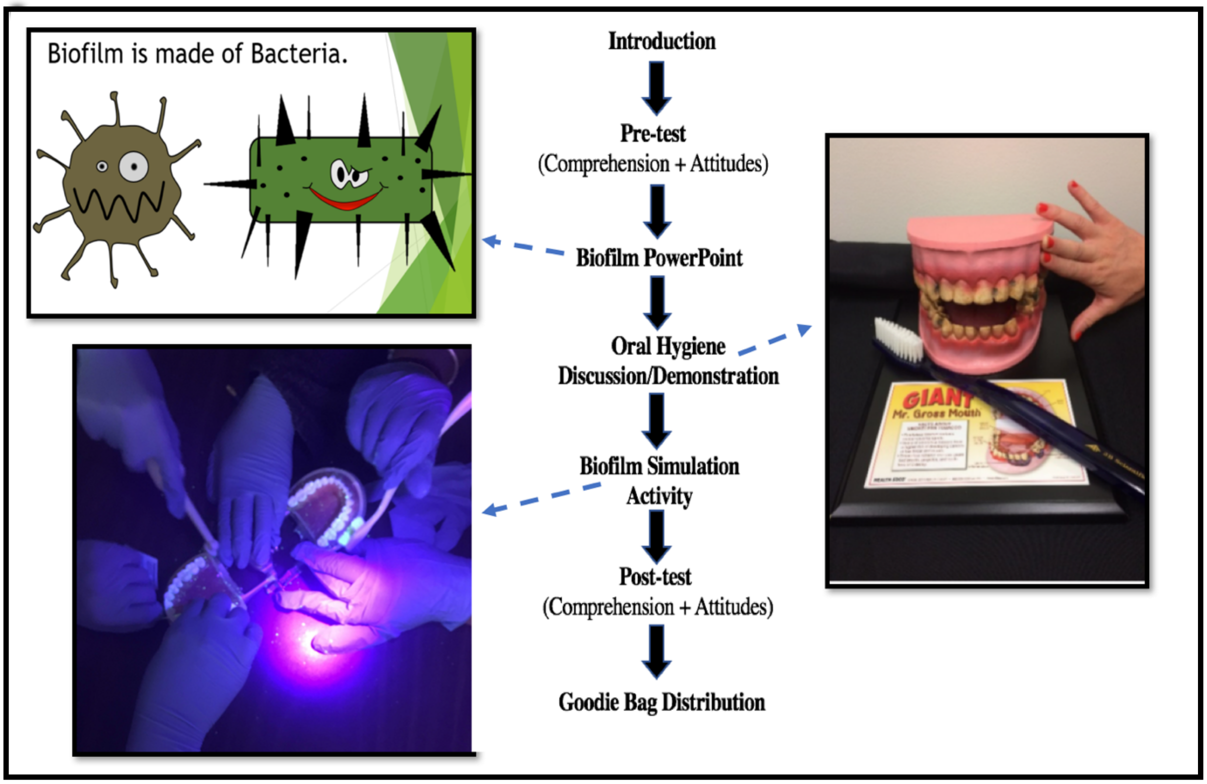

Figure 1: Flow Chart of Classroom Session outline in sequence

Several resources were peer-reviewed and published as an instructor's guide under the title "A Novel Oral Health Outreach Activity for Elementary Grade Students" with the Life Science Teaching Resource Community, which is an online network for educators in life sciences across a wide spectrum of grade levels. This instructor's guide includes a step-by-step instruction set of the PowerPoint script with animation prompts, access to the Biofilm PowerPoint, pre- and post-tests and surveys, a full question-answer set for the oral hygiene discussion, and a step-by-step guide to the biofilm simulation activity (Downes, 2017). This website allows free access to scientific education resources to educators registered with the site.

In order to deliver an abstract concept like biofilm to the minds of young students, there is a need to combine theory, in the form of lecture, demonstration by example to encourage mirroring of techniques (Shukla, 2012), questioning to engage students in thought processes (Socratic Method), and activity (constructivism/synthesis.) In the ideal design the education theories of instructivism (narration), Socratic method, and constructivism (synthesis) are unified into a one-hour classroom session. This is the optimum design for the aim, with a final activity that calls on the highest level of learning according to Bloom's Taxonomy: Synthesis (Bloom, 1956). As learning styles are as diverse as the students who occupy them, the aim is to target the information with a variety of methods, transmitting the information to all and deeply solidifying it in most.

Due to the fact that not every teacher has time to lecture on the theory portion, it was apparent that there is a vast number of students who do not receive effective education on oral health in the classroom setting. Thus, the universally-unifying platform of YouTube was used to make this resource available to all students globally with internet access. With the design of this video, it was sought to engage the different approaches to learning by including information reinforced by questions, student participation with a small experiment (testing biofilm with tongue), and attention-grabbing animations. This video was also equipped with captions that can be translated into any language provided by YouTube. Thus, where this study used the Biofilm PowerPoint (Figure 1), teachers with limited time can conveniently substitute the "What is Biofilm" video (C. Miller, 2017).

Development of Powerpoint

In order to make this project possible, an engaging PowerPoint was developed using Microsoft PowerPoint with *de novo* images. An occlusal, open-mouth view of the oral cavity was designed under PowerPoints' "insert" tab using the "shapes" and almost exclusively the "curve" line option. Default colors were changed using "shape fill" and "shape outline." The same method was used for developing cartoon-style images of bacteria which were designed to be frightening yet approachable for a gentle introduction to disease. A slight gradient was applied to the teeth in an attempt to achieve contour. A toothbrush was also designed with this method, topped with a red-white-blue nurdle (Marcus, 1970) of toothpaste inspired by Colgate™ toothpaste. Biofilm was represented surrounding each tooth's outline using a green, slightly-transparent shade using the "glow" feature under "shape options." The size and intensity of "biofilm" could be adjusted with the size and transparency options. Each slide did not require recreation of each image, but by screenshotting, cropping the image, importing it back into PowerPoint, and using the "remove background" feature, images were able to be reused and reassembled into new combinations for the PowerPoint.

Animations were incorporated using PowerPoints' "animations" feature to create a motion-filled PowerPoint to maintain attention and provide visual aids to the theory portion. With each slide, a script was developed to answer every question in our learning objectives: "What is biofilm?" "How does it grow?" "How can it be bad for us?" and

“How do we prevent it from growing?” These questions were answered with a text narrative that the animations followed and eventually served as the basis for the suggested classroom script in the teacher’s guide (Downes, 2017), most of the script of the online video, and the foundation for the subtitles of the video. Once the script was finished and correct PowerPoint prompts included, the PowerPoint could be exported to a video platform and recorded.

Video Creation

The video was created using the PowerPoint, teacher’s guide, and Camtasia (Camtasia, n.d.), a video editing and creating software. Using Camtasia, the PowerPoint was uploaded and the time spent on each slide was indicated using the program’s timing features. Each slide corresponded to an audio recording, each of which were individually editable. The audio bits were recorded separately and then closely edited together to allow flow. The final step was captioning, which included typing verbatim the audio sections and aligning with appropriate slides and timing. The video was then downloaded and uploaded to the University of Louisville’s Physiology YouTube page (C. Miller, 2018).

Hygiene Discussion and Demonstration

The hygiene discussion was used to help students reinforce lecture concepts and learn new techniques to apply to the biofilm simulation session. Hygiene principles were based on the ADA patient-education flipbook (ADA, 2019a). This was the gold-standard resource for method and duration of brushing, the correct flossing technique (using a “C-shaped” tooth-hugging floss technique,) and how mouthwash is important because even after brushing and flossing, 75% of the oral cavity still has a layer of biofilm. Students were shown a “Giant Mr. Gross Mouth (Education, 2020)” and “Mr. Clean Mouth (Edco, 2020),” large oral cavity tooth models, to highlight the difference between a lifetime adhering to excellent oral health habits and a lifetime of oral health neglect. The comparison intends to spark student interest and associate good habits with health, and lack of habits with disease. The Modified Bass Technique (Poyato-Ferrera, 2003) was demonstrated on the large “Mr. Dirty Mouth” model of the oral cavity with a giant toothbrush for students to have a macro-view representation of the technique. The C-shaped flossing technique was demonstrated on Mr. Clean Mouth due to better embrasure spaces. This discussion was paired with frequent questioning to reinforce basic concepts (Downes, 2017)[i]. The discussion and demonstration were designed to equip students with an armamentarium of techniques and guidelines to practice immediately following in the Biofilm Simulation activity (Downes, 2017)[ii].

Biofilm Simulation

The biofilm simulation activity is an innovative, novel method of understanding oral disease initiation that is unprecedented in oral health education. This activity not only simulates the behavior of biofilm in the oral cavity with precision, but it allows children to interact with the “biofilm” safely by removing risk of contamination with actual bacteria. The substitution of biofilm with glow gel made this possible. Several different types of glow-in-the-dark paints and were tested. Rubie’s Glow in the Dark Cream Makeup (Rubie’s Costume Company, Inc, 2020) was superior due to brightness of

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[i] found in the “Oral Hygiene Discussion” portion of the “Instructor’s Guide for Oral Health Outreach Activities”

[ii] found in the “Biofilm Simulation Exercise” portion of the “Instructor’s Guide for Oral Health Outreach Activities”

glow and resistance to manual removal and so was selected for the continued use in the activity. Two days prior to the classroom session, the glow gel, was placed on dentoform teeth models by applying a generous amount on a plastic toothbrush and scrubbing in order to cover every surface of the dentoforms possible, being careful to wiggle the brush and material into interproximal spaces, fissures, and the gum tissue. The covered dentoforms were allowed to dry overnight and the following day. The glow gel simulates biofilm well because, like biofilm, it is difficult to see with the naked eye, difficult to remove, and mimics biofilm's behavior accurately in interproximal spaces (i.e. it is maximally removed using the C-shaped technique.)

Crates were assembled (for a classroom of approximately 24 students, eight boxes were arranged with an estimated three students per team.) These boxes were filled with supplies to equip the students with everything needed to practice hygiene techniques discussed in the oral hygiene discussion session. The boxes included three pairs of extra-small, latex-free gloves, a plastic hand mirror, one floss packet, an electric toothbrush, a traditional plastic toothbrush, and a blacklight flashlight. The gloves and plastic hand mirror were not essential to the activity but helped the students to "play dentist" and to interact with the biofilm simulation in an accurate way (as with real biofilm protection is vital.)The two types of toothbrushes allowed students to increase exposure to hygiene techniques available and to experiment with maximal biofilm-removal between the two. A blacklight flashlight was included to check progress at two minute intervals (the ideal brushing time.)

Biofilm Activity in Classroom Session

Students were divided into roughly eight groups of three students. A two-minute timer was set to allow each student an experience of the ideal brushing time. It was explained to the students that there is a layer of synthetic biofilm on the teeth and gums and that their goal was to remove as much as possible in two minutes. It was explained that they would remove the maximum amount if they utilized the techniques demonstrated for brushing and flossing. One student in each group was the designated flosser, with one electric-brusher, and one traditional brusher. At the end of the two-minute period, blacklights were used to examine the extent of biofilm removal. Techniques were adjusted as needed. Most often, students needed a demonstration of the flossing technique. Students within teams then traded jobs for another two-minute brushing session followed by blacklight reexamination.

Goodie bags

Goodie bags were assembled at the same time as gel-application to the dentoform mouth models. The bags included temporary tooth tattoos, a “smile” neon wristband, a packet of floss for older students, and a two-minute hourglass-style plastic brushing timer (Smilemakers, 2020). The brushing timer serves as the real accountability for the students’ brushing habits and is a way for them to bring home what they learn in the classroom session for long term change and perhaps as a conversation base for the education of parents and other family members.

Assessment Instrument (Survey)

Teacher Perception Evaluation

Immediately following the classroom session, the science teacher was given six statements to address using Likert scale with 1= strongly disagree, and 5= strongly agree as shown in Table 1. The survey included five open-ended questions to gain qualitative data regarding the program's design and possible improvements. Each of these statements was carefully designed by the research team to address the reactions, learning, behavior, and impact that the resource had on students as observed by their teacher.

Table 1. Teacher Post-Survey Statements

Statement 1: The science outreach programs were at an appropriate educational level.
Scale: Likert

Statement 2: The science outreach programs increased students' enthusiasm for science.
Scale: Likert

Statement 3: Were there any specific incidents with students in which you noticed increased enthusiasm?
Scale: Open Response

Statement 4: The science outreach programs helped to increase the students' exposure to science careers.
Scale: Likert

Statement 5: The presenters in the science outreach program were enthusiastic.
Scale: Likert

Statement 6: The presenters in the science outreach program were knowledgeable.
Scale: Likert

Statement 7: The presenters in the science outreach program interacted well with the students.
Scale: Likert

Statement 8: What is the biggest strength of the science outreach program?
Scale: Open Response

Statement 9: What are the potential areas for improvement in the science outreach program?
Scale: Open Response

Statement 10: Did you, as a teacher, personally benefit from the outreach program? (Please explain)
Scale: Open Response

Statement 11: Do you have any further comments you would like to share?

Scale: Open Response

For all Likert Responses: 1= Strongly Disagree, 5= Strongly Agree

Student Comprehension

Students were evaluated for current knowledge of oral hygiene and biofilm before and after the intervention. Pre- and post-tests were identical in format, differing only in timing of administration. Questions were designed to target fundamental principles crucial to understanding biofilm, how it grows, and what students can do to combat it. The tests consisted of five questions each.

The first question and associated answer options were "Another name for Plaque is" fungus, rot, biofilm, or decay, with the correct answer being "biofilm." This question was designed to make the connection that this "biofilm" is the same thing as "plaque" on teeth. This connection is essential for tying in the relevance of the entire intervention.

The second question asked "Where is the dirtiest place in your teeth?" with an original image created in PowerPoint of an oral cavity with arrows indicating the different options: A) "Top of tooth (where you chew)" B) "On the side of tooth (where you smile)" or C) "In between teeth." The correct answer was "C," solidifying that most plaque accumulates in the interproximal niches. This question was created to provide a foundation for the importance of flossing.

The third question was "When does the most plaque grow?" with options of A) "Right after a big, sugary dessert" B) "While you sip a big, sugary soda" or C) "Overnight while you are sleeping." The correct answer was "C," emphasizing the importance of brushing before sleep and immediately after sleeping when the bacterial load is the highest.

The fourth question was “What is the goal brushing time?” with A) “30 seconds” B) “1 minute” C) “2 minutes” and D) “5 minutes” as options. The correct answer according to the ADA (ADA, 2019b) and a systematic review of 59 studies is “C) 2 minutes”(Slot, 2012). This concept was reinforced with the biofilm simulation exercise, allowing students to experience what a true two-minutes of brushing feels like and also by providing students with their own two-minute brushing timers in their goodie bags. This principle is vital to combating biofilm “,” 2019) and is a guideline that has poor compliance given that nearly half of Americans fall short of this suggested brushing time (Murphy, 2019).

The fifth question was “Let’s say you’ve brushed your teeth and removed all plaque from your teeth. How much time does it take for a new layer to form?” Answer choices included three minutes, one hour, two days, and one week, with the correct answer being “three minutes.” This question was designed to emphasize the resilience and unremitting growth potential of biofilm. By understanding this concept, students are less likely to skip a morning or evening brushing session, aware that biofilm develops rapidly.

The five comprehension questions were printed on double-sided white sheets of paper and distributed to students before the classroom session began and again immediately following the final biofilm simulation activity. A line for each student’s name was provided on the sheets to allow a precise comparison of individual student progress. Students completed the pre- and post- tests with pencils, a silent atmosphere, ample time and no collaborative opportunities.

Student Interest in Science

The third-grade student attitudes toward science were evaluated before and after the intervention. A four-question survey was created from available, validated Science Interest Inventory Surveys with simplified statements such as “Science is interesting to me,” and “I like asking questions about science” (Hasni & Potvin, 2014). Students responded using a modified Likert scale consisting of smiling, straight, or frowning faces. The numerical scale utilized by the traditional Likert scale to define level of agreement or disagreement is likely too advanced to act as an accurate empirical evaluation of a child’s experience, given that the comprehension level of most students in this study are not yet in Piaget’s “formal operational stage.” This stage of learning is defined by a capability for abstract thought defined as "assumptions that have no necessary relation to reality” (Piaget, 1972). The age at which this capability is typically reached, according to Piaget, is 11 to approximately 15–20. Smiley Face Likerts (SFL) have been used in pediatrics for many years as a subjective measurement of a child’s perception of pain (Tatla, 2014). This scale has been used more recently to measure children’s response and engagement to new activities (Read, 2002).

Peer Review of Resources

All resources used in the outreach classroom design underwent peer review by University of Louisville professors prior to implementation. Resources reviewed include the “What is Biofilm?” PowerPoint, the pre-test and post-test, modified Likert scale science-interest surveys, and teacher’s survey prompts.

Data Analysis

Dependent t- tests were used to determine statistical significance between the pre- and post- intervention data. Significance was defined as $P<0.05$. SPSS was used to determine statistical significance (IBM Corporation, Armonk, New York).

Support

This work was supported in part by a basic grant from the University of Louisville School of Medicine and a support grant from the Dean's Office of the University of Louisville School of Dentistry.

CHAPTER 4

RESULTS

Student Interest in Science

To gauge a baseline in student interest in science, a pre-survey was administered to the third, fifth, and sixth grade students at the beginning of each outreach presentation. This four-question survey was created using a modified Science Interest Inventory Survey with simplified statements. Corresponding responses were a frowny face corresponding with “no” and 0 points on a Likert scale, a straight face corresponding with “maybe” and a value of 1 point, and a smiley face corresponding with “yes” and assigned 2 points. Therefore, each student could get up to eight points (two points for each of four questions) for those highly interested in science and as little as zero points (zero points for each of four questions) for those with little interest in science. The compiled responses are shown in Table 2. These same survey questions were then repeated at the conclusion of the hour-long outreach presentation. A within subject dependent t-test determined no statistically significant difference between the pretest and posttest responses ($p>0.05$) for all three classes. The data suggests that the students were interested in science before the intervention and the intervention did not increase their interest level.

Table 2: Student Interest in Science

	Third Grade	Fifth Grade	Sixth Grade
Pre-Survey (mean ± SD)	4.26 ± 1.97	4.41 ± 1.94	5.65 ± 1.90
Post-Survey (mean ± SD)	3.26 ± 2.02	4.32 ± 1.99	5.60 ± 1.82

Table 2: Pre-survey and post-survey mean scores with SD by grade. A within subject dependent t-test determined no significant difference between the pretest and posttest responses ($p>0.05$) for all three classes.

Student Comprehension of Information

Student comprehension was measured using a five-question pre-test and post-test instrument for all three classes. The pretest was given immediately before the onset of any educational interventions to establish baseline knowledge of the content. On the pretest, each student could get up to five points (one points for each of five questions) for those who had previous knowledge of the material and as little as zero points (zero points for each of five questions) for those who had no previous knowledge of the material. The posttest was given immediately following the intervention to assess the short-term retention of learned information. On the posttest, each student could get up to five points (one points for each of five questions) for those who retained the information well and as little as zero points (zero points for each of five questions) for those who retained no information. Scores were converted into percentages of correct answers and subjected to inferential statistical analysis for reporting. A within-subjects dependent t-test determined statistically significant differences between the pre-test and post-test responses ($p<0.05$) for all three classes. The data suggested that all three classes retained the information and comprehended the subject content short-term by achieving higher scores. See table 3 and figure 2 for representation of the data.

Table 3: Student Comprehension Data

Oral Health: 3rd Grade (n=20)	Pre-Test	Post-Test
Average ± SD	32.00 ± 22.85	89.00 ± 19.97

Oral Health: 5th Grade (n=22)	Pre-Test	Post-Test
Average ± SD	38.18 ± 17.36	90.00 ± 14.80

Oral Health: 6th Grade (n=19)	Pre-Test	Post-Test
Average	50.53 ± 19.29	98.95 ± 14.59

Table 3: Student Comprehension Data. A within-subjects dependent t-test determined statistically significant differences between the pretest and posttest responses ($p<0.05$) for all three classes.

Figure 2: Student Comprehension Data

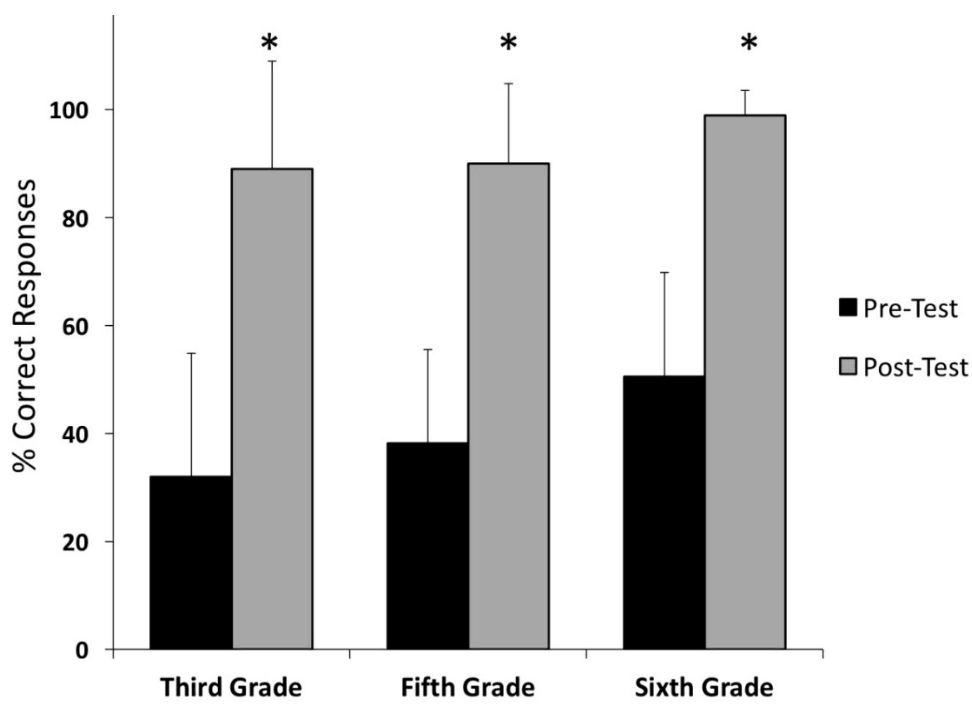

Figure 2. Student Comprehension Data for Third, Fifth, and Sixth Grades: Pre- and Post-Tests. Data represented as student averages with error bars indicating standard deviations. Results show a statistically significant, 57%, increase on post-tests (n=20), 51.82% (n=22), and 48.82% (n= 19) for third, fifth and sixth grades respectively (*$p<.001$, student's t test).

Teacher Perception Evaluation

The science teachers were given a survey consisting of eleven statements to address: six statements using Likert scale with 1= strongly disagree, and 5= strongly agree as shown in Figure 3 and five open-ended questions to gain qualitative data regarding the program's design and possible improvements. Each of these statements were designed to address the reactions, learning, behavior, and impact that the resource had on students as observed by their teacher. The teachers in this study responded with strong agreement to each statement, as shown in Figure 3, by selecting a consistent response value of 5.

Figure 3: Teacher Perception Evaluations

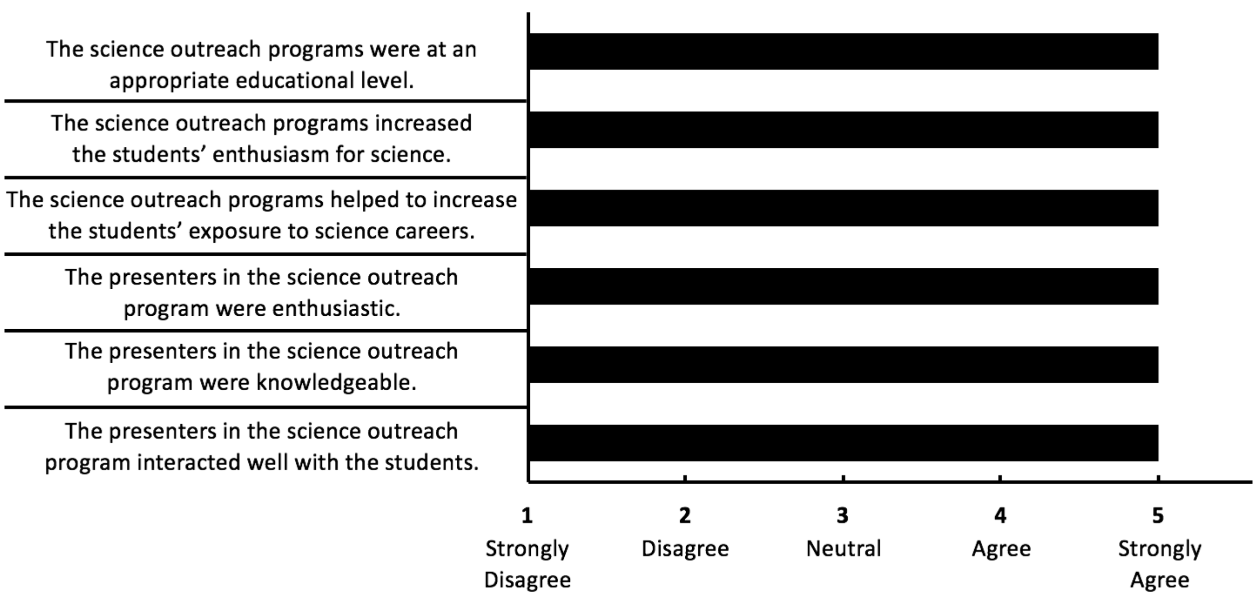

Figure 3: Teacher Post-survey Response Data for Third, Fifth, and Sixth Grades: Data displayed as average Likert scale response. Results show a consistent Likert response of 5/5 or 100% agreement with survey prompts. Standard deviation= 0. N=3

Open-ended questions in the survey were designed to elaborate on observations and to invite suggested changes that the program's design might undergo for improvement. The science teachers noticed a marked increase in enthusiasm (see "statement three" from Table 1) when students "were able to do the hands-on activities, such as brushing, flossing the dental model teeth and using the black light to check the cleanliness of the teeth" and while "wearing gloves, using the toothbrush and black light." They reported the greatest strengths of the outreach program as "the discussion along with the activity of brushing the teeth" and the "interactive toothbrushing/flossing model. The students LOVE THAT!!" When asked if, as a teacher, they personally benefited from the program, responses included "I think the program helped to reteach the importance of dental hygiene to my students," "YES!! This helps to cover part of unit that sometimes gets missed due to lack of time. Thank you," and "Yes!! I love this program."

A few suggestions for improvement were made, including one-on-one help reading the questions to students struggling with reading. Another suggestion was to allot one blank page per student to record questions to save for the end of the session in order to prevent redundancy of information and allow a structured flow of classroom time.

CHAPTER 5

DISCUSSION

Summary and Conclusions

Utilizing active learning modules and hands-on simulation *improves* memory retention and recall of oral health literacy information. A one hour active learning intervention does not significantly increase student interest in science given the population studied.

All classrooms encountered in this study experienced statistically significant increases in oral health comprehension with an average increase of 57%, 51.82%, and 48.82% for third, fifth and sixth grades respectively. This increase in comprehension about biofilm and its relation to oral health is the result of an evidence-based classroom session that utilizes the techniques and concepts of active learning, Piaget's theory of cognitive development, and constructivism, which places the learner as the center and reference point ("Constructivism (philosophy of education)," 2019; Fosnot, 2005; Piaget, 1972). These techniques enabled the dramatic results exhibited in this study. As an extension to third, fifth, and sixth grades, this study supports the findings of Freeman et. al's study on active learning, which states that active learning strategies applied to undergraduate science classes increased performance (Freeman et al., 2014). These results lend a supporting body of evidence to future studies on simulation especially in the context of oral health literacy and further validates successful past studies examining the effectiveness of simulation and other active learning practices (Bommer et al., 2018; Comer, 2005; Hawkins et al., 2008; Kalmakis et al., 2010; Lin & Song, 2018; Nilsson et al., 2017; Partin, 2011; Persky, 2017; Thompson & Bonnel, 2008).When asked what the greatest strength of the classroom session was, the teachers indicated that it is the combination of engaging lecture and simulation: "the discussion along with the activity of brushing the teeth," endorsing the advantage of the constructivist approach.

Interestingly, in the current study, there was no significant increase in third, fifth, or sixth grade student interest level in science following the one-hour presentation on oral health concepts. It is worth noting, however, that students did express an above-average level of interest (average of 4.77 on a combined 8 point Likert scale) prior to the outreach programming.

The teachers' (n=3) feedback and observations cannot be overlooked when determining student interest. The strong support from unanimous 5/5 Likert-scale responses prompt a reexamination of student interest data. From the teachers' point of view, a definite increase in "enthusiasm for science" was observed. In the open responses, one teacher indicated the greatest strength of the program as "interactive toothbrushing/flossing model. The students LOVE THAT!!"

There are a few theories for the dichotomy of data between the teacher responses and the science interest survey responses. One potential explanation is that the prompts to measure student interest were not appropriately designed to connect these classroom sessions about bacteria and oral health with the vast field of science. Perhaps more targeted prompts might be "learning about bacteria is interesting" or "I want to be a dentist." Another theory is that perhaps this one-hour intervention was not enough time to result in an immediate change of one's long-held level of interest in science. Another theory is that there was an increase in interest with science but that the external evidence of change was more apparent to the teacher than the student's self-awareness permitted. While no theory is confirmed, the latter seems to be the most likely.

Interestingly, studies by other research groups have found an increase in student interest levels using similar methods (Becker, 2002). However, the majority of these studies did focus on older, middle-school level students. For the current study, interest levels were not assessed in the middle-school level students.

Implications for the Field and Gaps Filled

This study with its range of supportive data across age groups addresses the gap in literature as to whether active learning with simulation, interactive PowerPoints, and modules can improve oral health literacy among at-risk populations. The simulation of biofilm in combination with other active learning techniques like interactive PowerPoints and classroom discussion breaches a major gap in literature as it concretizes the abstract, bridges cognitive stages, and utilizes constructivism by creating student-centered learning for oral hygiene instruction instead of parent-centered instruction. Comprehension percent increases within this study indicate the effectiveness of the active learning approach in improving oral health literacy in at-risk populations.

Long term implications of comprehension data may be vast. In the words of sociologist and philosopher Herbert Spencer (1820-1903) "The great aim of education is not knowledge but action" (Spencer, n.d.). In light of this phrase, it can be inferred that because information was successfully transmitted, action may follow suit. The hope is that students can take this new knowledge and apply it as demonstrated in the classroom. The hope is that the students spread their knowledge by teaching those in their immediate circle, including parents, friends, and relatives, about the surprising and interesting characteristics they now understand about, thereby creating a ripple effect. The hope is that a subconscious, unmeasurable by survey, positive degree was made in attitude toward the sciences and that this deeper knowledge of biofilm leads to action, empowerment, and, perhaps in the future, an increase in much-needed STEM careers and public servants for the state of Kentucky. What if every science class were designed with active engagement of students and sought to concretize the abstract? Perhaps these small degrees of change would amount to a 180 degree turn toward the positive. Some may find these potential implications to be exaggerated or far-fetched, but that is not at question. What is important is that they are possible.

Furthermore, in attempting to assess the long-term effects of this research, the global potential for impact cannot be overlooked. The team recognizes that not every classroom in the world has a teacher who knows about or has access to Life Science Teaching Community Resources, or has the budget or resources to launch this type of classroom activity. However, an increasingly vast portion of the globe has access to the internet. As of 2019, 57% of the world's population has internet access ("Digital 2019: Global digital overview," 2019). The "What is Biofilm?" video contains the major learning points on oral health principles in an active learning format and is available with captions that translate into every language available by YouTube, which includes the top

10 spoken languages in the world and 25 additional ones (C. Miller, 2017; Robertson, 2008). This broad spectrum of access will facilitate learning in communities and individuals where internet alone is required. Furthermore, this allows spontaneous access to information for anyone who is on the internet and would like to access it.

Limitations

Limitations of this research include the relatively small sample size of students (n= 61). While the students in the sample are at the J Graham Brown School, which is known for its diverse assortment of students ("About Brown," 2019), more participants will always strengthen the potency of research. In the future, the hope is that this approach will continue its trend of increasing student comprehension about essential oral health concepts.

Another limitation to this study is the short time of intervention. A single 1-hour classroom session is likely not enough to reorient a lifetime of oral health habits. Daily reinforcements were attempted by giving students goody-bags which included two-minute timers (Smilemakers, 2020) to act as a reliable reminder and accountability factor in their daily routines. Retention of good oral health habits is thus facilitated. The other aspect of short intervention time is that it does not appear to be sufficient to allow a full change in attitude about the field of science. Quarterly oral-health review sessions or watching the "What is Biofilm?" video with students about the oral health concepts would be ideal for long-term retention and reinforcement of habits (C. Miller, 2017).

One limitation that has been suggested is the "lack of an experimental control." This is not a true limitation as the students act as their own controls (before and after). To deprive a subset of students the advantage of a novel approach to education would be unethical.

Future Research

It is desired to track the interest levels of the current third graders, as they progress through the various outreach programs over the course of the next 4-5 years. By that method, longitudinal changes in student interest levels of science can be ascertained. Additionally, our group would like to examine retention of content provided in the earlier programs over the course of the students' education. This process may be challenging, however, due to time constraints with each class, movement of students to new classroom sections, etc.

Suggested future research is to expand the depth of detail at which the subject of biofilm is addressed and presented for higher grade levels. A classroom session should be designed for 7^{th}-12^{th} grades which would include a gradient or two more of detail using this classroom session as a scaffold. A few examples of detail that could be considered include: types of bacteria involved in carious process and periodontal disease, specific caries risk factors, the relation of systemic disease and oral health, pH relationship for the demineralization of enamel and dentin, and the role of inflammation in periodontal disease. Further gradients could be used for 12-16^{th} grades. Both extensions would only effect the extent of *theory* in the PowerPoint. The commonality of the biofilm simulation exercise would remain constant as the principles of oral hygiene techniques in the management of biofilm do not change according to education level.

Further research may be in the education of parents of children and caretakers of the elderly. For caretakers, the biofilm classroom session would extend to its accumulation on prostheses and its effects on soft tissue. It could also reinforce visible signs of candida infection, proper denture cleansing, and the need for annual oral cancer screenings from a dental professional. Biofilm simulation exercise in the case of a caretaker for the elderly could involve an altered approach: instead of, or in addition to, a dentoform as the carrier of biofilm, a removable prosthesis could be used. Empowering those who are caretakers (of children, adults, or elderly) is advantageous and essential as it benefits the student participating *and* those in his/her care.

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