An Investigation of a Biofeedback Intervention at a Secondary School as an In-Classroom Self-Regulated Learning (SRL) Strategy

by

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Abstract of the Dissertation
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Self-Regulated Learning (SRL) opportunities decrease when students reach secondary education (Casey & Caudle, 2013). Nonetheless, adolescent students are still expected to apply SRL skills and achieve academic success, all with predeveloped brains and bodies vulnerable to psychophysiological dysregulation. The COVID-19 pandemic exacerbated adolescents' deficits in SRL and led to chronic school absenteeism, with 16 million U.S. students considered chronically absent, compared to the pre-pandemic figure of 8 million students (NEA, October 2023). Time spent in the classroom is essential to learning and, therefore, was also measured as a variable in this study and referred to as Time To Learn (TTL) (Borg, 1980; Brown & Saks, 1986; Calma-Birling & Zelazo, 2022; Cotton & Savard, 1981; Drysdale, 2023; Dynaski et al., 2004; Frazier & Morrison, 1998; Gettinger & White, 1979; Lauer et al., 2006; YRBS, 2021; Zadina, 2023).

This 6-week empirical study delved into the potential of a psychophysiological intervention as a Tier 1 learning strategy for SRL, organized using Zimmerman's SRL model. A quantitative analysis was conducted using several *t*-tests to assess SRL and TTL differences between a Treatment Group (TG) and a Control Group (CG) of 10th-grade students ($N = 30$). Empirical data were collected by a pretest/posttest design during the Metacognitive Self-Regulation (MSR) instrument and by a methodical collection of percentage of time data from the school's check-in/check-out system measuring TTL.

Results from inferential statistics revealed that students who used biofeedback for 6-weeks did not show a significant difference in SRL compared to those who did not. Similarly, Time To Learn (TTL) opportunities did not provide sufficient evidence between the TG and CG to suggest a statistical difference; therefore, the null hypotheses for both research questions could not be rejected. Interestingly, the study revealed that the CG made more improvements in SRL but spent the least amount of time in the classroom. Meanwhile, the TG showed the least improvement in SRL and spent the most time together in the classroom. While not providing definitive answers, these findings highlight new avenues for research. For example, this information may lead future researchers to inquire about the relationship between SRL and TTL and how time out of the classroom may relate to SRL. Further exploration related to these findings may deepen the understanding of SRL and TTL. Overall, this study revealed some discoveries similar to that of other research, contributed valuable data to mitigate the identified problem facing the adolescent population, and added value to the field of educational psychology. This study supported previous research stating that SRL cannot be measured in isolation (Boekaerts & Corno, 2005). Students who received biofeedback may have shown some improved SRL, but it cannot be determined that biofeedback was the only factor influencing students' improvements in SRL.

This study introduced a novel approach to SRL practices specific to the secondary level. Before this study, the potential of a biofeedback intervention as an in-classroom SRL strategy at the secondary level was largely unexplored, with most research focused on elementary and postsecondary education. The biofeedback intervention in this study was widely accepted among students, parents, administrators, and community stakeholders, suggesting the likelihood that SRL opportunities will continue to be supported at the secondary level. This study adds to the field of educational psychology by highlighting the current problems that adolescents face and identifying psychophysiological approaches that support SRL.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

DEDICATION

To my children, Julianna and Landon: You are my greatest joy and inspiration. I hope my work will inspire your own learning journey and empower your growing minds to face adversity with grit and determination. Remember, “good energy and a good attitude” are the keys to success and happiness. I love you endlessly and am proud to be your mother.

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CHAPTER ONE

Introduction

For adolescents, the aftermath of the COVID-19 pandemic exacerbated difficulties with Self-Regulated Learning (SRL), increased chronic school absences, and intensified maladaptive behaviors (Calma-Birling & Zelazo, 2022; Drysdale, 2023; YRBS, 2021; Zadina, 2023). Amidst the pandemic, adolescents continued to evolve through their critical period of development and profound change while being disrupted by unprecedented challenges in their educational settings. School shutdowns and social isolation brought about poor academic work habits, limited motivation, and fear of the future (Zadina, 2023). In a qualitative study during the pandemic, adolescents were surveyed and felt most worried about their future related to college transition (Scott et al., 2021). School supports typically available to these youth before the pandemic were compromised, making experiencing major life events uncontrollable (DuBois et al., 1992; Lessard & Puhl, 2021). While research continues to unveil the full impact of the pandemic, recent literature overwhelmingly revealed adolescent skill deficits associated with SRL as a leading indicator of pandemic-related disruptions among youth (Calma-Birling & Zelazo, 2022; Zadina, 2023).

This present study targeted the adolescent student population (ages 15, 16, and 17), who were most vulnerable to the pandemic’s consequences because of their developing brain amid the challenges of significant psychophysiological changes and school-learning interruptions (Calma-Birling & Zelazo, 2022; Jensen & Nutt, 2015). The study addressed the neurobiological markers that make the adolescent population the most impactful developmental stage for learning self-regulation skills (Murray &

Rosanbalm, 2017). Since the pandemic, high school students have had a much harder time coping with daily life challenges and academic demands, as evidenced by a decline in school attendance and emotional resiliency (Walker, 2023). Currently, secondary schools are tasked to address this problem by increasing students' skills with SRL. The skills and abilities that comprise SRL are the key predictors of lifelong learning and academic success (Dignath & Büttner, 2008; Panadero & Alonso-Tapia, 2014; Steffens, 2006).

This present study investigated a biofeedback intervention as a potential SRL strategy. Biofeedback is the process of measuring the body's physiological states while providing immediate feedback to the mind on how to change one's psychophysiological activity (Weerdmeester et al., 2020). Many people already use biofeedback through smartphones, watches, and other activity-tracking devices (Cook & Sayeski, 2022). The study implemented a self-administered biofeedback activity (less than 5 minutes) in a classroom of adolescent students (Treatment vs. Control Group) and investigated potential connections with SRL and Time To Learn (TTL). The literature reviewed called upon future research like this study to emphasize utilizing biofeedback technology in schools to help students become better self-regulated learners. The present study provided a unique approach to SRL in schools by investigating a biofeedback intervention with adolescent students.

Background of the Problem

History of the Problem

This study was designed to emphasize the problem high school students experience with SRL amidst the aftermath of the COVID-19 pandemic. The background of the problem made adolescents the most vulnerable to the pandemic's consequences because of their developing brains, neurobiological responses to stress, and psychosocial development (Chin et al., 2023). The research reviewed demonstrated that the history of SRL and adolescent vulnerabilities were critical factors in understanding students' current learning capabilities and potential influences associated with this study's outcome.

Self-Regulated Learning (SRL)

Self-Regulated Learning (SRL) is a term that was first used in 1980 as a classroom management technique that places the responsibility of learning on the student (Bandura, 1986). SRL means that students can set their own learning goals, determine their learning approach and process, use self-monitoring strategies, and effectively self-evaluate (Cai et al., 2020). SRL is the systematic process by which learners activate and sustain cognitive processes toward attaining learning goals (Schunk & Zimmerman, 2008). "This technique is valuable because when students develop the ability to learn and think independently, they can learn by themselves inside or outside of school, without the teacher's guidance" (Gupta & Mehtani, 2017, p. 85). SRL involves goal setting, concentration, choosing effective organizational strategies, being resourceful, self-monitoring, time management, and self-efficacy (Gupta & Mehtani, 2017; Schunk & Ertmer, 2000). SRL is the student's capacity to actively participate in their learning and independently navigate their learning experiences (Bardach et al., 2023). When faced with obstacles, an effective self-regulated learner will know what metacognitive strategies to apply during learning instruction to be successful (Bardach et al., 2023).

Educational history showed the makings of SRL during post-World War II when students were classified into ability groups to optimize learning (Zimmerman & Schunk, 2001). The curriculum targeted ability-matching group instructional procedures (Zimmerman & Schunk, 2001). During the early 1960s, learning instruction began to draw attention to the financially disadvantaged early childhood experiences (Bloom, 1964; Hunt, 1961). Humanistic psychologists designed schools to make them “less threatening” during a posttraumatic period (Bloom, 1964; Hunt, 1961). It was a time in education when grade promotion and curricular requirements were more flexible and focused on students’ social adjustment (Zimmerman & Schunk, 2001). Schools pledged to make better efforts to communicate and involve parents and families (Zimmerman & Schunk, 2001). Instructional goals focused on intellectual deficits and disadvantaged children with innovative teaching methods (Bloom, 1964; Hunt, 1961). Unfortunately, the postwar educational reform led to declining national achievement (Zimmerman & Schunk, 2001). There was a “disillusionment” to focus solely on eliminating poverty (Bloom, 1964; Hunt, 1961). Consequently, in the 1970s, education commissioned for change in the reports “Back to Basics” and “A Nation at Risk,” led by the National Commission on Excellence in Education (Gardner et al., 1983). Educational change investigated educational accountability and brought back the quality of teaching, curriculum requirements, and achievement standards (Gardner et al., 1983; Zimmerman & Schunk, 2001). While well intended, these reforms removed responsibilities from the students, employing them in a *reactionary* role as learners (Zimmerman & Schunk, 2001). Emphasis was placed on the role of the teachers and educators and *not* on the role of the students (Zimmerman & Schunk, 2001).

Alternatively, SRL emphasizes the role of the student in all facets of education and learning (Dong, 2023). For example, to develop the skill of writing, a *student* must know how to self-monitor, self-evaluate, and adjust when necessary (Graham & Harris, 2000; Graham & MacArthur, 1988). The writing process involves creating a writing product that requires the *student* to engage in goal-oriented behavior and problem-solving (Dong, 2023; Graham & Harris, 2000). Cognitive and academic demands can complicate the writing process, which makes SRL skills all that more important to know and possess (Dong, 2023; Graham & Harris, 2000). SRL employs students to engage cognitively, motivationally, and behaviorally in academic activities (Zimmerman, 2005).

In 1989, a famous study (commonly referred to as the "Marshmallow Experiment") demonstrated the self-regulation ability of children using marshmallows and delayed gratification (Mischel et al., 1989). The study examined if children would choose one marshmallow sooner rather than wait for two marshmallows later (Mischel et al., 1989). The study found two resulting behaviors– children who did not wait and those who attempted to wait (Mischel et al., 1989). "A hallmark of self-regulation is the ability to resist the temptation of an immediate reward for a later larger reward, known as delay of gratification" (Casey & Caudle, 2013, p. 4).

Forty years after the prominent study, Casey and Caudle (2013) studied the *same* individuals from the original study and replicated the study using a go/no-go test. The follow-up study found that the same individuals who could not stop themselves from immediately eating the marshmallow (and thus not getting two) also had difficulty stopping themselves when a positive social cue was present, even when instructed not to respond (Casey & Caudle, 2013). However, if a neutral cue was presented, they had no problems habituating their response (Casey & Caudle, 2013). The study confirmed that developmental and individual differences impact self-control (Casey & Caudle, 2013; Cell Press, 2019). Casey and Caudle (2013) charged that individuals with diminished self-control might be especially vulnerable during adolescence and have heightened emotional sensitivities to environmental cues, supporting the pandemic's influence on SRL.

Consequently, self-regulation is essential for a successful life of learning and is especially important for vulnerable adolescents (Zadina, 2023). Conflicts from the pandemic impacted effective self-regulation (Bradley et al., 2007; Cai, 2020; McCraty, 2005); therefore, educators must teach adolescents how to confront their challenges during the school day and generalize them into their daily lives. Regardless of intellectual disabilities or cognitive levels, SRL is essential for all students (Zadina, 2023). *All* students need engagement and better focus (Zadina, 2023).

Adolescent Vulnerabilities

Adolescents are the most vulnerable and, therefore, benefit the most from SRL strategies (Calma-Birling & Zelazo, 2022; Jensen & Nutt, 2015). G. Stanley Hall, an American psychologist and founder of the scientific study of adolescence, regarded the stage between childhood and adulthood as a discrete developmental stage (Jensen & Nutt, 2015). Adolescence is a period when one faces new life challenges and demands. Hall was a pioneer in making the biological connection between adolescence and puberty (Jensen & Nutt, 2015). This psychophysiological connection was this study's foundational purpose of choosing a biofeedback intervention. During adolescence, the brain regions responsible for cognition and emotional and behavioral regulation develop, facilitating increased capacities for self-awareness, self-direction, and self-regulation (Chin et al., 2023). Moreover, three critical factors in adolescence support why this population was the most appropriate group for this study's intervention: the adolescents' developing brain, their dysregulated behavior, and their social susceptibility. To best support adolescents, one must fully appreciate the burden of their vulnerabilities.

Brain Maturation. The development of self-regulation is directly linked to brain maturation in adolescence and brain functioning (Pas et al., 2021). During adolescence, the brain's growth varies across regional structures, with neural changes occurring during skill acquisition (Casey et al., 2019). Acquisition (the learning and development of a skill) changes the process of brain maturation by building upon previously learned skills to support enhanced learning (Casey et al., 2019). In adolescence, the brain develops a more controlled integration of previously learned executive functioning skills. Associated with SRL, executive functions are a set of cognitive skills used to control thoughts and behaviors associated with the prefrontal cortex of the brain (Best et al., 2011; Diamond, 2013; Shoemaker et al., 2013). Executive functioning and self-regulation skills are crucial for social-emotional behaviors and academic achievement (Lin et al., 2020). While continued growth in executive functioning and self-regulation occurs, there are nonetheless neurological roadblocks that get in the way of the adolescents' promising brain (Jensen & Nutt, 2015; Sapolsky, 2018).

Brain maturation is not linear; it occurs in developmental periods of neural processes (Casey et al., 2019). The brain's cortical and subcortical regions are improving their connectivity at the onset of adolescence due to the increase in myelination of white matter (Asato et al., 2010; De Leeuw et al., 2017; Ladouceur et al., 2012). The anatomical changes in the brain improve the behavior functions needed for effective self-regulation (Asato et al., 2010; De Leeuw et al., 2017; Ladouceur et al., 2012). Nonetheless, adolescents have a slow-developing frontal lobe (prefrontal cortex) that is known to derail the processing of the specific brain regions impacting self-regulation (Asato et al., 2010; De Leeuw et al., 2017; Ladouceur et al., 2012).

Since the prefrontal cortex is temporarily offline, adolescents will often be forced to rely on their limbic system (their emotional center) to help them process information. As a result, this population is vulnerable to being overwhelmed emotionally by the pressures of school, family, social life, and physical changes (Rotto, 2022). Somerville and Casey (2010) acknowledge the presence of a brain imbalance during this period of development, which causes adolescents to over-rely on and overemphasize the reward-centers and subcortical regions of the brain, which are first to develop, as opposed to accessing the prefrontal regions of the brain which are last to develop (Casey & Caudle, 2013).

The brain region responsible for self-regulation is the anterior cingulate and lateral prefrontal cortex (Sapolsky, 2018). Neuroscience has demonstrated that adolescents undergo rapid changes in these areas of the brain that are most responsible for self-regulation, which supports why this population is so vulnerable to environmental influences (Jensen & Nutt, 2015; Romeo, 2013; Schuitema et al., 2012; Shen et al., 2007). Therefore, adolescent students were the most appropriate population to direct the focus of this study. Neuroscience research explains that the brain is malleable and self-regulation skills are *not* automatically developed; therefore, SRL must be *taught* and practiced (Lin et al., 2019; Somerville et al., 2011; Somerville et al., 2010). This provides evidence demonstrating that self-regulation can be learned, making SRL interventions invaluable. With intervention, the malleable brain may have a better chance to develop adaptable self-regulation skills.

Storm & Stress. Hall claimed the stage of adolescence to be a period of "storm and stress" (Hall, 1904). The infamous storm of adolescent behavior takes its initial form at the aforementioned neuro-connections in the adolescent brain (Casey & Caudle, 2013; Hibbs, 2007; Jensen & Nutt, 2015). The proverbial storm results from adolescents trying to balance neurological changes while simultaneously adapting to their environment's dynamic shifts and demands (Jensen & Nutt, 2015). Consequently, the neurological changes evoke mental stress and erupt physical manifestations of a behavioral storm.

When adolescents are under a storm of stress (such as the stress from the pandemic), the brain's amygdala becomes activated, which then sends signals to the pituitary gland (at the base of the brain) to alert the adrenal gland (right above the kidneys) to release hormones (Jensen & Nutt, 2015). The body's glands produce hormones that circulate in the bloodstream and are vital to one's bodily functions (Jensen & Nutt, 2015). The adrenal gland creates a physical response of stress in the body by raising the body's heart rate, dilating blood vessels, and increasing oxygen (Hibbs, 2007; Jensen & Nutt, 2015). One's heart rate is an important marker of physiological resilience and behavioral flexibility, which is the measure at which biofeedback is employed (HeartMath Institute Science, 2024). During moments of mental and physical stress, the body's heart rhythms can become distorted, sending neural signals to the brain, ultimately inhibiting the cognitive functions needed for learning (HeartMath Institute Science, 2024). Research shows that learning to regulate the body's heart rhythms can calm the mind and body and resolve the storm (HeartMath Institute Science, 2024).

Most behaviors occur in school since more than 95% of U.S. adolescents spend much of their daily lives in school (YRBS, 2021, p.7). Recent data on risk-taking behaviors revealed by the "Youth Risk Behavior Survey (YRBS) Data Summary & Trends Report: 2011-2021" indicated a substantial increase in adolescent behaviors as it pertained to protective sexual behavior, experiences of violence, mental health, suicidal thoughts and behaviors (YRBS).

In 2021, student behavioral data also showed increases in drug and substance use, with 23% of high school students drinking alcohol during the past 30 days, 16% of high school students using marijuana during the past 30 days, and 18% of high school students using an electronic vapor product during the past 30 days. According to YRBS (2021), adolescents are at risk for experiencing violence, undergoing mental health problems, sexual risk behavior, substance use, and diminished academic success. Data exhibited an increased percentage of students who missed school because of safety concerns and experienced sexual violence (YRBS, 2021). "In 2021, 9% of high school students did not go to school because they felt unsafe either at school or on their way to or from school at least once during the past 30 days" (YRBS, 2021, p. 50). In 2021, almost half of the students who completed the survey (41%) felt sad or hopeless almost every day for at least two weeks and stopped their usual activities (YRBS, 2021). The research explained that adolescents were significantly worse at avoiding emotional distractions than unemotional ones compared to children or adults (Beaumont et al., 2023; Sparks, 2018). Moreover, an emotionally charged adolescent has more of a challenge to effectively self-regulate and problem-solve (Beaumont et al., 2023; Sparks, 2018). "Common behavioral changes during adolescence may be associated with a heightened responsiveness to incentive and emotional cues while the capacity to engage in cognitive and emotion regulation effectively is still relatively immature" (Somerville et al., 2010, p. 1).

Above all, the neurobiology and environmental changes that adolescents endure while attempting to learn at peak efficiency are challenging their efficiencies related to self-regulation (i.e., attention, self-discipline, task completion, and emotions) (Jenson & Nutt, 2015; Schunk & Zimmerman, 1994; Vink et al., 2020). This highlights a problem for adolescents, who might lack the skills to be effective self-regulated learners. As such, adolescents are vulnerable to poor decision-making, which can have long-term negative consequences (Murray & Rosanbalm, 2017). For these reasons, teaching adolescents strategies to become self-regulated learners is critical for shaping behavior change (Murray & Rosanbalm, 2017).

Psychosocial Development. During the Industrial Revolution, adolescents were treated like adults for economic reasons; however, by the end of the 1930s, adolescents lost their jobs, and the Great Depression forced them to enroll in high school and discover a new identity (Jensen & Nutt, 2015). According to Erikson's theory of psychosocial development (1968), the most crucial goal in adolescent development was to solve the "identity vs. role confusion" crisis. Adolescents are tasked with constructing a meaningful identity and finding a sense of belonging in their social habitat (Erikson, 1968). Erikson emphasized this critical period of adolescence as a time to differentiate between self and others and grow into an autonomous functioning individual (Erikson, 1968). Therefore, it is logical to assume that to be successful at this psychosocial stage, one must become a self-regulated learner.

Adolescents' psychosocial identity is formed by the influence of their peer relationships, which emphasizes the importance of interpersonal connections and the power of social approval (Jensen & Nutt, 2015; Ragelienė, 2016). These young adults are pressured by the high expectations associated with their age while stalled by barriers presented by their psychosocial development (Berzonsky, 1988).

A dramatic shift happens from middle to high school, with significant changes in the adolescents' school environment and academic tasks (Bardach et al., 2023). These shifts increase demands and responsibilities for adolescents' executive function capacities. They can become cognitively stuck by the new demands placed on them and may rely on the adults in their lives to do most of the SRL for them (Bardach et al., 2023). As they continue developing their metacognitive learning strategies required for SRL, adolescents still need some guidance and external support (Bardach et al., 2023; Schneider, 2008).

The National Association of School Psychologists (NASP) charged that executive functioning and self-regulation skills are crucial for academic and social-emotional learning and must be taught because such skills are not automatically developed in one's lifespan (Brozovich et al., 2021). Knowing this, adolescents *need* instruction on SRL to better prepare themselves for their new environmental and academic challenges (Bardach et al., 2023; Dent & Koenka, 2016; Jindal-Snape et al., 2020;). McClelland et al. (2018) explained that adolescent psychosocial development is a turning point in SRL. Research indicated that while adolescents have an increased need for independence, they show a decrease in academic engagement (Bardach et al., 2023; Mastrotheodoros et al., 2019). Academic engagement is essential for success in learning, which warrants attention to adolescents' psychosocial development. Research alerts parents and teachers to understand that SRL skills are not innate; skills can be improved with effort (Sparks, 2018), and overall values and practice supporting student autonomy should be encouraged (Bardach et al., 2023; Perry et al., 2006).

Past Approaches to the Problem

School systems have approached SRL activities through methods of journaling, reflective writing, and in-class mindfulness techniques (i.e., deep breathing and meditation) (Casey & Caudle, 2013; Utley & Garza, 2011). Both well-researched strategies have been known to support SRL (Casey & Caudle, 2013). Additional SRL approaches include recess and scheduled free time during the day (Casey & Caudle, 2013). A research study found that students who had recess were observed to be less fidgety and pay greater attention in class (Jarret et al., 1998). Literature supports the unstructured activity of recess for self-regulation across a wide range of developmental domains (Farbman, 2015).

SRL strategies may also include practicing relaxation techniques in the classroom to help students improve their focus (Casey & Caudle, 2013). The problem that occurs with these approaches is that children grow into adolescents, and these SRL practices are often removed (Casey & Caudle). Adolescents receive little to no self-regulation opportunities in their day to help prepare them for middle and high school. Recess and free time are either reduced or nonexistent, which limits their physical activity and ultimately removes the opportunity for SRL benefits. This exacerbates into a more significant problem for adolescents: adolescents are operating with an underdeveloped prefrontal cortex (responsibility for SRL), are given fewer opportunities to gain SRL skills, an increase of demands are being placed on their executive functioning at school (with changing classes, more independence, study time, etc.), and finally, simultaneously sending a message to adolescents that effective SRL outcomes are expected (Casey & Caudle).

Biofeedback

The Discovery of Biofeedback. Before biofeedback was introduced in 1969, the unnamed method was a historical practice through Indian medicine, yoga, and transcendental meditation (Peper & Shaffer, 2018; Satter & Valdiya, 1999). Ancient practices of improving the mind encompassed the whole body, including the heart and the brain (Green et al., 1979). This work began out of yogic practices of autonomic control and research by Lapides et al. (1957) and Kimmel (1967). By the end of the 19^{th} century, yogic disciplines attracted medical and philosophical attention through training systems using the mind and body (Sattar & Valdiya, 1999). By 1910, this training was called "autogenic training" (a self-generated or self-motivated training to help alleviate stress and psychosomatic disorders) developed by Dr. Johannes Schultz (German psychiatrist and psychotherapist) (Peper & Shaffer, 2018; Satter & Valdiya, 1999). At the same time, Sigmund Freud (Austrian neurologist and founder of psychoanalysis) had been treating patients with hypnosis and encountering unconscious resistance (Peper & Shaffer, 2018; Satter & Valdiya, 1999). Schultz believed that if he developed a procedure where patients were in control of the technique, it would be more effective (Peper & Shaffer, 2018; Satter & Valdiya, 1999).

Behavioral psychologists and applied theorists molded the psychophysiological formulation of biofeedback through cybernetics (the study of control and communication) during World War II (Sattar & Valdiya, 1999; Wiener, 1948), thus giving rise to the domain of self-regulation. In 1959, the first English translation of Schultz and Luthe's book, "Autogenic Training," arrived (Peper & Shaffer, 2018; Satter & Valdiya, 1999). Self-regulation techniques of autogenic training originated in Europe with Schultz's work on meditative exercises that elicited self-awareness and psychophysiological self-knowledge (Peper & Shaffer, 2018; Satter & Valdiya, 1999). Gardner Murphy (an American psychologist) joined the research by including biofeedback in the methodology and use of electrophysiological instrumentation for measuring unconscious physiological processes (Peper & Shaffer, 2018; Satter & Valdiya, 1999; Wiener, 1948).

At the beginning of the discovery of biofeedback, researchers argued that people could only learn to control skeletal muscle responses consciously, and autonomic processes (i.e., heart rate variability) could not be controlled (suggesting that it could only be classically conditioned) (Peper & Shaffer, 2018; Satter & Valdiya, 1999). However, pioneers of biofeedback dating back to the 50s and 60s demonstrated that autonomic responses *were* controllable (Peper & Shaffer, 2018; Satter & Valdiya, 1999). A landmark study by Neal Miller (an American psychologist and researcher) demonstrated that paralyzed rats could learn through operational control of their autonomic functions (DiCara & Miller, 1968). This research inspired future operant concepts to be applied in rehabilitating patients with spinal cord injuries (DiCara & Miller, 1968).

Operant behavior is the root of biofeedback and for learning, which collectively created a critical theoretical framework for the proposed study (Peper & Shaffer, 2018;

Satter & Valdiya, 1999; Thompson & Thompson, 2015). The foundational concepts and behavioral principles developed by B.F. Skinner (American psychologist and father of behaviorism) helped to frame the mechanics of biofeedback (Demos, 2019; Thompson & Thompson, 2015). Skinner's operant theory explains how responses can be voluntarily controlled and which cannot (Skinner, 1937; Staddon & Cerutti, 2003). This process applies to the origins of biofeedback and how the process of learning takes shape.

In 1966, in his sleep lab, Joe Kamiya, the father of biofeedback, used operant theory applications while monitoring patients' brain waves using electroencephalograms (EEGs) (Peper & Shaffer, 2018; Satter & Valdiya, 1999; Thompson & Thompson, 2015). He found that patients could learn to discriminate their brain activity when provided with feedback (Peper & Shaffer, 2018; Satter & Valdiya, 1999). Kamiya's research suggested that individuals could learn to control their consciousness through neurofeedback, one of the most promising forms of biofeedback (Thompson & Thompson, 2015). Thomas Mulholland (psychophysiological researcher) investigated how EEG biofeedback could produce physiological change through positive and negative feedback loops, which is a biological response that could help to understand human attention (Peper & Shaffer, 2018; Satter & Valdiya, 1999). Biofeedback research continued to be inspired by Erik Peper (applied psychophysiologist) and colleagues (Peper & Shaffer, 2018; Satter & Valdiya, 1999).

The Rediscovery of Biofeedback. Biofeedback is now a psychophysiological intervention supported by evidence-based research, efficacious studies, and accountability (PWEBS, 2023). It is most known for its non-pharmacological treatment of the body's self-regulation process (Walsh, 1983; Zadina, 2023). The biofeedback process involves systematic monitoring of one's physiological functioning through the use and acceptance of auditory or visual feedback to signal a behavior change (HeartMath Institute, 2020, 2018; Satter & Valdiya, 1999). A common example of biofeedback is using a thermometer to assess if a fever is present at the onset of the body feeling warm. If a fever is detected, the person will likely initiate behavioral change, such as taking a fever-reducer medication.

Biofeedback is not a new concept. However, it is not widely known among the public. Biofeedback research has demonstrated a connection between physiological responses from one's heart rate and body temperature to be within human control, which has thus inspired future research to assess its impact on controlling human learning (Peper & Shaffer, 2018; Satter & Valdiya, 1999). Biofeedback intersects multiple disciplines, such as neuroscience, psychology, neurology, internal medicine, sports coaching, nursing somatic therapy, and physical therapy (Satter & Valdiya, 1999; Sauer et al., 2010). In 2013, the American Academy of Pediatrics listed biofeedback as the best, evidence-based, level 1 intervention for attention and hyperactivity behaviors (i.e., Attention-Deficit/Hyperactive Disorder, ADHD) (AAP, 2013; Arns et al., 2014; PWEBS, 2023). The academy reported biofeedback to have adequate statistical power with significant pre- to post-study change, thus supporting its treatment efficacy (AAP, 2013). Unfortunately, some literature and media report that biofeedback is too time-intensive to help teach self-regulatory skills, and therefore, people are more likely to profit quickly by using prescription drugs or surgical procedures (Arns et al., 2014). Possibly, this is why the medical model has overlooked biofeedback as a treatment. However, with more research, providers have found more clinical applications of EMG (electromyography) biofeedback that can be helpful, notably in treating tension headaches (Sattar & Valdiya, 1999; Sauer et al., 2010). Promising research on using biofeedback strategies in education has shown statistical improvements in student behavior and academic achievement (HeartMath Institute, 2024). SRL and biofeedback support the body's ability to monitor and regulate the mind and body through conscious actions (McCraty & Zayas, 2014). By teaching biofeedback in school, students are also learning and practicing SRL, which they may integrate across settings and generalize into their daily lives (McCraty et al., 2016; McCraty et al., 2020).

Current Status of the Problem

COVID-19 Implications

Student Dysregulation. The complexities of educating students following the pandemic have brought to the forefront of public debate the current needs in school systems that must be better developed. Navigating adolescents' stress in secondary school has always been a challenge and a part of life's developmental stage (Zadina, 2023). However, the pandemic indeed increased the pressures on adolescents when returning to in-person learning after school shutdowns and remote instruction (Scott et al., 2021). "The COVID-19 pandemic is an example of a chronic stressor for which many adolescents were unprepared" (Chin et al., 2023, p. 2). The study by Lessard and Puhl (2021), conducted during the height of the pandemic, found that out of a sample of 5th to 12th-grade students, academic concerns were particularly relevant for high school students (9th to 12th grade). Furthermore, they found that female students reported more frequent pandemic-related academic stressors than male students (Lessard & Puhl, 2021).

This finding was also supported by previous research on pandemic stress among adolescents (Ellis et al., 2020; Nocentini et al., 2021).

In the October issue of *National Education Association (NEA) Today*, it was reported that the pandemic led the nation's students into a mental health crisis (Walker, 2023). According to the NEA, school leaders and administrators reported a lack of preventative mental health interventions before the school shutdowns (Walker). As a result, educators are currently overwhelmed and burdened (Walker). Despite federal funds from the American Rescue Plan and the Bipartisan Safer Communities Act, the resources and attention to the student crisis declined (Walker). In March 2023, the Centers for Disease Control and Prevention reported that 42% of high school students were suffering from stress and anxiety (a 50% increase from 2011) (Walker). "Students of all ages and backgrounds are experiencing these heightened levels of stress, anxiety, and trauma" (Walker, p. 39). This suggests that no student is exempt from this and that everyone can experience stress and anxiety.

NEA recognized the current burden confronting school counselors to respond to the aftermath of the crisis (Walker, 2023). Their roles have changed into something that their role was not designed for. School counselors are being asked to play the role of an outpatient therapist, with overwhelming requests by parents and teachers to meet with their students individually and treat emotional dysregulation (Walker). Counselors have been forced to be reactive when best practices teach them to be preventative or proactive. The American School Counselor Association president, Jill Cook, prescribes that school counselors are not therapists and should not be treated as such (Walker). Cook charges that schools should support students to ensure that they are getting the help they need in school with Tier 1 preventative strategies for social-emotional learning and less on reactive methods that are not sustainable (Walker). Given this, Tier 1 prevention was the effort of the present study.

According to NEA, teachers are “playing catch-up” to get their students the help they need, and counselors are putting out fires out of reaction to students’ mental health needs (Walker, 2023). Students have a much harder time coping with daily life challenges and educational demands (Walker, 2023). Student behavior is becoming more challenging to manage in the classroom (Walker, 2023). From March 2020 to June 2021, one-third of teachers reported they were attacked or verbally harassed (Alvarez, 2023). During the same time, the American Psychological Association gave a survey to approximately 15,000 Pre-K to 12th-grade teachers and discovered that one-third of teachers have reported being threatened (i.e., verbal threats, cyberbullying, intimidation, or sexual harassment) by one of their students, within that year (Alvarez, 2023). “Fourteen percent of teachers said they have been victims of physical violence from students” (Alvarez, 2023, p. 50).

Teachers reported that students lack focus, have trouble paying attention, and have more problematic behavior (Zadina, 2023). Zadina explained that educators' views of the needs in the classroom need to change. For too long, educators have focused on the “foreground” of educational strategies, pedagogical practices, and theoretic structures. While still necessary and essential, there needs to be a shift in the approach (Zadina). Zadina claimed that the educational focus should move more to the “background” to what is not always transparent: the psychological and emotional climate of the classroom. Student engagement and attention are impacted by the state of one’s brain (Zadina). What are the emotional states of adolescent students? Are the students ready and available to learn? Teachers should take the proverbial "temperature" of the classroom climate before addressing the foreground of academic learning (Zadina).

Social-emotional learning is not new to education, with many programs and evidence-based practices available (Boekaerts & Cascallar, 2006; Boekaerts & Corno, 2005; Zadina, 2023). However, the suggested shift in learning may be more expansive than social-emotional learning and instead suggest a broader gestalt approach that may address whole-person learning (Moffitt et al., 2011).

School Attendance. The current status of school attendance is a problem for adolescent youth and overall educational systems. School attendance decreased during the pandemic and has remained a problem (NEA, October 2023). Public school enrollment fell by 1.2 million during the first two years of the pandemic and continues to rise, with more students transitioning into homeschooling or private school (NEA). Additionally, many families have relocated out of state, impacting reporting data (NEA). "An analysis by the Associated Press and Stanford University found that in the 21 states with available data, an estimated 230,000 student absences could not be explained" (NEA, October, p.13). Changes such as this can lead one to wonder why students are not returning to the traditional school classroom.

The Massachusetts State Education Commissioner from the Department of Elementary and Secondary Education announced on October 24th, 2023, that chronic absenteeism in Massachusetts public schools increased by 73% between 2019 and 2023 (Drysdale, 2023; see Appendix A). Data from the Massachusetts Department of Elementary and Secondary Education (DESE) showed that chronic absenteeism grew during the COVID-19 pandemic and has not returned to pre-pandemic rates (Drysdale). In 2022-2023, approximately 1 in 4 Massachusetts students missed 18 or more days of the school year. Among all grades, absenteeism has doubled since the pandemic (Drysdale). Younger students missed over 10% of class time (Drysdale).

The Commissioner believed that the cause of absenteeism was due to the pandemic's forced disruption of "school-going culture" (Drysdale, 2023), suggesting that the habit had been broken and is now a challenge. In Massachusetts, a "chronic absence" is missing 18 days out of the 180 days of the school year (10%). This definition was created by research showing evidence that academic implications occur by 10% of missing school days (Drysdale). This problem caused the Commissioner to launch a campaign called "All Hands on Deck," which provided over $4 million to school districts to track attendance better and provide students with opportunities to make up work (Drysdale). Since the pandemic's peak, attendance has improved slightly; however, the rate continues to be high (Drysdale). Current high school rates are the most significant (with 29.9% of chronic absenteeism) compared to the elementary and middle school rates (Drysdale).

Student attendance data from this study's public secondary school was analyzed as part of the reviewed research (see Appendix B). The Massachusetts Department of Education, by the end of the 2022-2023 school year, reported the following: 8.3% of high school student absences, 9.2% high school students reported "chronically absent" (10% or more absences in the school year) and 3.2% & high school students reported "chronically absent" (20% or more absences in the school year). In comparison, pre-pandemic data (from the 2018-2019 school year) reported the following student attendance data: a reported average total of 8.0% of high school student absences, 10.1% of high school students reported "chronically absent" (10% or more absences in the school year) and no data collected for chronically absent beyond 20% of the school, suggesting that this was not a measurable area of concern at that time. Interestingly, data for chronic absences beyond 20% only began to be collected by the 2021-2022 school year (with its first data point at 2.3% of high school students).

Attendance issues are prevalent, and research showed that schools have more control than they may know (Drysdale, 2023). While families and communities continue to hold responsibilities circling attendance issues, there are clear impacts and influences that schools can do to help with this problem. Every Student Succeeds Act (ESSA) focuses on advancing equity and excellence for all students, particularly disadvantaged and high-need students. This act holds states accountable for reporting data such as chronic absenteeism. As a result, DESE believes these efforts can improve education by supporting the whole student (Drysdale, 2023). The "whole student" strategy aligns with a gestalt idea that learning instruction goes beyond the foreground of student learning (Zadina, 2023). DESE aims to "support the whole student and foster joyful, healthy, and supportive learning environments so that all students feel valued, connected, nourished, and ready to learn" (Riley, 2023, p. 8). The goal of the DESE is to help students be more engaged in school, especially academically, emotionally, socially, and physically. The department hopes that by implementing targeted support, attendance will increase.

Summary

Overall, the implications of the COVID-19 pandemic changed adolescents and made it more difficult for them to regulate their emotions and executive functioning skills

(Calma-Birling & Zelazo, 2022; Miller et al., 2021; Zadina, 2023). SRL is an essential learning strategy that was unmistakably lacking in the students' pre-pandemic lives and disabled their motivation and continued growth to learn independently. NEA charged that there is a significant need for school systems to invest in preventative strategies to help students with their mental health and self-regulation. The research reviewed makes one wonder if biofeedback could be used as a Tier 1 classroom-wide intervention and reach *all* students. The literature overwhelmingly showed that all students should be taught SRL skills for lifelong learning success (Dignath & Büttner, 2008; Panadero & Alonso-Tapia, 2014; Steffens, 2006).

In 2022, the American Psychological Association (APA) called on psychologists to rebrand the field by shifting away from a one-to-one intervention approach and instead broadening efforts towards a preventative and behavioral health approach (Weir, 2023). Kenneth Dodge, Ph.D., professor of psychology and public policy at Duke University, believes psychologists can significantly impact education by rethinking individualized psychological interventions (Weir). Stress will continue to surround adolescents; therefore, it is impossible to prevent it. Nonetheless, research confirms that reduction, tolerance, and regulation can be achieved. Considering adolescents' neurobiological vulnerabilities, research promotes teaching youth resiliency and the skills related to SRL.

Statement of the Problem

The COVID-19 pandemic introduced remote learning, limited peer socialization, and interrupted Self-Regulated Learning (SRL) (Casey & Caudle, 2013; Tyborowska et al., 2023). National Public Radio (NPR, 2023) reported on "All Things Considered" that since the pandemic, school absenteeism has increased, noting that in Spring 2022, 16 million U.S. students were considered chronically absent, compared to the pre-pandemic figure of 8 million students. Data encapsulate the problem that adolescent students are struggling to attend school regularly and remain in the classroom (NEA, October 2023). Why are students avoiding school? Are they struggling to be resilient? Time spent in the classroom is core to learning and performance, and with more time out of the classroom, students may be more likely to struggle as independent learners and problem-solvers (Borg, 1980; Brown & Saks, 1986; Cotton & Savard, 1981; Dynaski et al., 2004; Frazier & Morrison, 1998; Lauer et al., 2006). While some data are known to support the importance of time spent in class, it is unknown how Time To Learn (TTL) influences students' self-regulation.

SRL is the chosen strategy for this study, which is the process in which students activate metacognitive, affective, and behavioral processes while simultaneously applying skills of planning, monitoring, and self-evaluating (Zimmerman, 2000). Research suggests that SRL can be developed and mastered (Zimmerman, 2000), which motivates one to explore if it could potentially mitigate some of these unwanted post-pandemic concerns. Research refers to SRL as a core component for lifelong learning and future success, which, for this reason, makes SRL an essential topic to explore in this study (Dignath & Büttner, 2008; Panadero & Alonso-Tapia, 2014; Steffens, 2006).

SRL influences academic performance as a learning process that students undergo to help control and direct their learning (Akhtar & Mahmood, 2013; Bembenutty, 2005; Santrock, 2006). Ormond (2020) charged that SRL is "a general ability to take charge of one's behaviors, for instance, by keeping counterproductive impulses in check" (p. 383). An additional problem adolescent students are up against regards their dysregulated brain development, most notably the part of their brain most responsible for self-regulation (frontal lobe), which does not fully develop until the mid-20s. Research confirmed that SRL is a skill that needs to be taught and is not a natural learning process; therefore, teaching and training adolescents how to engage in SRL effectively leads this study to explore the training impacts of biofeedback in school (Lin et al., 2019; Somerville et al., 2011; Somerville et al., 2010).

Biofeedback is a process that informs an individual of his or her psychophysiological activity, allowing for voluntary control and positive change in the mind and body (Fuller, 1984). There is a solid history of biofeedback having evidence-based efficacy for treating mental health disorders, cognitive disorders, substance abuse, and psychiatric disorders (Russo et al., 2020), with the highest strength of reliability for treating attentional deficits and behavioral disorders (PWEBS, 2023). There is limited research regarding the psychophysiological strategy of biofeedback in the field of education at the secondary level. Therefore, research has not yet clarified biofeedback as an effective in-classroom SRL strategy for the adolescent population. Considering this, continued advocacy for the relevance of psychophysiological learning strategies in educational disciplines is warranted.

The following study investigated a biofeedback intervention (the independent variable) as an in-classroom SRL strategy by testing the effects on two dependent variables: 1) SRL and 2) Time To Learn (TTL). The intervention was delivered to an adolescent population (ages 15, 16, and 17) and divided into a Treatment Group (TG) and withheld from a Control Group (CG).

The specific questions addressed by the research were:

RQ1: Is there a significant difference in *Self-Regulated Learning (SRL)* among the students who received the biofeedback intervention compared to those who did not?

H_O: There is no significant difference between *Self-Regulated Learning (SRL)* among the students who received the biofeedback intervention compared to those who did not.

H_I: There is a significant difference between *Self-Regulated Learning (SRL)* among the students who received the biofeedback intervention compared to those who did not.

RQ2: Is there a significant difference in *Time To Learn (TTL)* opportunities among the students who received the biofeedback intervention compared to those who did not?

H_O: There is no significant difference between *Time To Learn (TTL)* opportunities among the students who received the biofeedback intervention compared to those who did not?

H_I: There is a significant difference between *Time To Learn (TTL)* opportunities among the students who received the biofeedback intervention compared to those who did not?

Purpose of the Study

This study aimed to investigate a biofeedback intervention as an in-classroom Self-Regulated Learning (SRL) strategy and the potential differences with Time To Learn (TTL). Ideally, if a significant finding is found between the TG's SRL and TTL compared to the CG, it would be possible to advocate for school-wide support for biofeedback technology as an SRL strategy for all students.

This research addressed the problem adolescents are having with SRL by investigating a biofeedback tool as a potential learning strategy for SRL. The study explored whether this brief strategy, implemented before classroom instruction, would make a difference in students' time spent in the classroom, making them more available for learning. This study's insight into psychophysiological approaches in education can help direct future research related to SRL. This research study responded to APA's request to shift away from the one-to-one intervention approach and instead lean towards a preventative and behavioral health approach, which was also advocated in reviewed literature and by professional organizations.

The literature strongly suggests that studies need to strengthen the focus on a more intentional and targeted SRL strategy, including cognitive and emotional regulation skills. "Many current programs are comprehensive and diffuse, which may weaken the impact on specific self-regulation skills" (Murray & Rosanbalm, 2017, p. 4). Students are the most profitable from this investigation because they gain the benefit of learning about their unique psychophysiological connection regardless of the findings. Stakeholders (parents, teachers, and school administrators) will also gain knowledge by learning more about their students' SRL potential. Finally, the purpose of the study was to highlight the current issue adolescents face in school, demonstrate a need for school-wide SRL strategies in the classroom, and explore a potential learning strategy to mediate the problem.

Definitions of Terms

For the present study, the following definitions of terms were used:

Achievement Points. The sum of coherence scores added up every 5 seconds (HeartMath Institute, 2018).

Adolescence. The transition from childhood to adulthood begins with the onset of puberty and ends with successful independence from the parents (Casey & Caudle, 2013).

Biofeedback. The use of instrumentation to detect the psychophysiological process of which the individual is not typically aware and which may be brought under voluntary control (Fuller, 1984).

Coherence. Describes when the heart and brain work together efficiently or perform optimally (McGraty et al., 2016).

Coherence Score. The average current score is tallied automatically every 5 seconds and displayed in red, blue, or green zones on the Inner Balance App (HeartMath Institute, 2018).

Heart Rate Variability (HRV). The measure of time between heartbeats (Zadina, 2023). This is the commonly occurring beat-to-beat changes in heart rate (HeartMath Institute, 2018).

Metacognition. Refers to the awareness, knowledge, and control of cognition (Zimmerman & Moylan, 2009).

Psychophysiology. The study of the interrelationships between the mind and body (Schell & Dawson, 2001).

Self-Regulated Learning (SRL). The systematic process by which learners activate and sustain cognitive processes toward attaining learning goals (Schunk & Zimmerman, 2008).

Time To Learn (TTL). The percentage of time all students are together in class in the presence of learning instruction (Gettinger & White, 1979).

Limitations of the Study

It is important to address a few limitations of the study. These limitations included a small and nonrandomized sample size, environmental and genetic factors, testing approaches and methods, and unpredictable covariates that could arise.

Meta-analysis research on using biofeedback for physical and mental health outcomes typically recommends more than 1,000 participants. Most biofeedback research includes small sample sizes with up to 51 participants (Creswell, 2014). Researchers recommend using a large enough sample size that adequately reflects the population from which it is drawn (Creswell, 2014). Small sample sizes, like this study, can undermine internal and external validity (Creswell, 2014). The study used a quasi-experimental approach, which resembled a true experiment but cannot be claimed as such because the participants were not randomly assigned to conditions. Participants were selected via convenient sampling within pre-established classrooms that adhered to regularly scheduled meeting times of the school day. There were limitations with the convenient sampling procedure; however, due to the nature of the classroom-wide intervention, true randomization was not appropriate.

Environmental and genetic factors can play a role in the study, which may yield potential limitations. The intervention was designed to target all students as a Tier 1 intervention, and therefore, special populations and gender differences were not analyzed as separate entities. Such marginalized groups that may have learning disabilities or other physical and mental handicaps may have unique backgrounds and genetic factors that make learning and behavior change difficult. For example, behaviors are a response to nature and nurture; therefore, uncontrollable factors in a student's unique background can create barriers to change (Casey & Caudle, 2013). Additionally, the study did not address neuroscience differences among genders (Jensen & Nutt, 2015). Science has proven gender differences in neural anatomy in early fetal life, specifically hormonal differences in the hypothalamus, a brain region with responsible influences linked to SRL (Jenson & Nutt, 2015). This may suggest that genders could respond differently to this study.

This study collected pretest/posttest data on SRL using a questionnaire readily used in SRL research. Sound information can be collected from a small sample, and questionnaires are easy to administer to a small sample. However, the disadvantage of questionnaires is that the subjects' responses may contain bias due to the potential desire to put a socially accepted response. Using a pretest/posttest design for SRL can bring additional threats to internal validity with the integrity of the intervention and instrumentation implementation. This concern was addressed during the training phase of the intervention prior to data collection. Furthermore, history, maturation, and mortality are typical limitations of the pretest/posttest approach that were considered.

CHAPTER TWO

Review of the Literature

This chapter reviewed three essential areas of literature: *Biofeedback Training Interventions*, *Self-Regulated Learning (SRL) in Education, and Time To Learn* (TTL), including theoretical frameworks supported by research and literature.

Biofeedback Training Interventions

Biofeedback can be a powerful tool to support student learning (Frank, 2023). The science behind the psychophysiological technique has been used to achieve students' resilience and improve cognitive processing, academic achievement, and overall self-regulation (Frank, 2023; Russo et al., 2020). Moreover, biofeedback has evidence-based efficacy in treating mental health disorders, cognitive disorders, substance abuse, and psychiatric disorders (Russo et al., 2020). There is also substantial evidence to support improvements in one's heart rate variability, emotional regulation, and academic success (Aranberri-Ruiz et al., 2022; Bearden et al., 2023; Bothe et al., 2014; Bradley et al., 2007, 2010; McCraty, 2005; McCraty et al., 2016; McLeod & Boyes, 2021).

In education, biofeedback training interventions have improved students' readiness to learn, focus, and restore feelings of well-being (Frank, 2023). The Blue Menu of Evidence-Based Psychosocial Interventions for Youth, regularly updated using the PracticeWise Evidence-Based Services (PWEBS) Database for the period of April 2023 to September 2023, reported biofeedback to be "the best support" with the highest strength of evidence (for reliability of findings) for attention and hyperactivity behaviors (the most common mental disorder in children; reported by the National Center for Health Statistics, 2024).

Biofeedback interventions work through the psychophysiological connection between the mind and body. Understanding how this relationship communicates (*the psychophysiological connection*) will better help address students' behavioral responses (*fight, flight, freeze*) and explain the shared mechanisms responsible for activating learning (*operant conditional theory*).

The Psychophysiological Connection

The mind and body hold a strong psychophysiological connection that has long been researched and represents the foundational mechanics of understanding biofeedback. The relationship between the brain and the heart is a new concept in the field of educational psychology, especially for classroom-based learning strategies (Zadina, 2023). Despite that, Zadina (2023) charges that "It is time to bring them to the forefront so that current education practices and strategies can be more effective" (p. 3). Recently, extensive research from the National Aeronautics and Space Administration (NASA) has demonstrated how brain-body activities can impact how one learns (NASA, 2023). Research supports a connection between the mind and body through laboratory experimentation and neuroscience metanalysis (NASA, 2023).

The scientific data discovered about the relationship between the mind and body are often referred to as "psychophysiology" (Andreassi, 2000). Standard researched measures in psychophysiology receive biofeedback from one's heart rate, skin conductance, skeletal muscle activity, and emotional arousal (Schell & Dawson, 2001). Many neuroscientists and researchers have attempted to define the term psychophysiology. Andreassii (2000) defined psychophysiology as "the study of relations between psychological manipulations and resulting physiological responses, measured in the living organism to promote understanding of the relation between mental and bodily processes" (p. 1). In a similar fashion and more directly defined, this study used the definition by Schell and Dawson (2001), which defined psychophysiology as the study of the interrelationships between the mind and body. A review of the research on psychophysiology helps support the validity of the neuro-reciprocal dialogue between the mind and body and the importance for why this study is furthering its research.

In April 2023, a published study measured the connection between the body and the mind through an experimental research design using functional magnetic resonance imaging (fMRI) methods (Gordon et al., 2023). This recent study was conducted to replicate previous studies by Penfield and colleagues (1937) using brain scanning to determine psychophysical connections. Gordon et al. (2023) administered fMRI brain scans on seven healthy adults while resting or performing tasks. The researchers combined their results with three larger fMRI datasets from the Human Connectome Project, the Adolescent Brian Cognitive Development Study, and the UK Biobank, totaling a large sample of 50,000 people. Findings from the Gordon et al. (2023) study added clarity to the previous research conducted by Penfield et al. (1937), which found that the brain mapping for non-movement regions of the brain was connected to parts of the brain that involved thinking, planning, mental arousal, pain, and control of internal organs and functions (like heart rate and blood pressure).

The images from the experiment showed that while the non-movement areas did not activate on the scans during physical movement, they did become active when the person *thought* about moving (Gordon et al., 2023). This suggests that thoughts hold critical importance in the brain and have an incredible influence on the body. This study also supported NASA's research on how thoughts and movement play a role in learning skills. Interventions that promote mind and body connections have also been shown to improve attention, spatial awareness, handwriting, and reading skills (Gordon et al., 2023; NASA, 2023; Zadina, 2023). Additionally, the notion that the mind and body are connected has led researchers to explore how this connection can explain psychosomatic behaviors.

Fight, Flight, Freeze

Post-pandemic life has magnified adolescents' behaviors and how they respond to their environment (Beaumont et al., 2023; YRBS, 2021). The "fight-flight-freeze" response is a well-researched coping/defense mechanism that can help explain why adolescents are having a difficult time demonstrating SRL and shed an understanding for the purpose of this study (Ellis et al., 2020; Hibbs, 2007; Nocentini et al., 2021).

The fight-flight-freeze response to stress is the human's emergency response system working to survive and stay safe from perceived fears (Hibbs, 2007). Adolescents may have developed real post-pandemic fears or may have perceived fears that cause them to struggle with SRL in the classroom. The fears from their mind alert their body's emergency response system to respond by running away, which "requires rapid movement of large muscle groups in the legs, hips, and arms. For muscles to move, they need fuel. To get the fuel to where it's needed, the heart must pump faster and harder" (Hibbs, 2007, p. 17). A rapid heartbeat is the most common physical response to fear and stress and is the measure at which biofeedback operates (Hibbs, 2007).

When the mind is experiencing stress and the body is experiencing trauma, the muscles in the body require blood and oxygen to defend against the stress. Unfortunately, while this emergency response attempts to motivate the muscles to act (i.e., fight and flight), symptoms of rapid breathing and dizziness occur (Hibbs, 2007). This is because blood in the brain is being reallocated to the muscles in the body. When the muscles use up the body's fuel, the body begins to perspire with sweat (Hibbs, 2007). At this point, the mind's perception of the stressful event can sometimes become overreactive with feelings of danger (i.e., freeze), shutting down the digestion track and leading to nausea and stomach pains (Hibbs, 2007). When the mind reframes the experienced stress as not threatening, the body will calm itself and return to homeostasis. Considering this, it is clear that the mind has a powerful influence over the body, which may be a reason why students "flee" the classroom and become task or school-avoidant.

The body's autonomic nervous system (ANS) is comprised of the sympathetic and parasympathetic nervous system. The sympathetic system is the body's automatic reaction in times of crisis, which may result in a "fight, flight, and freeze" response (Bjorntorp, 1991; Brunner et al., 2002; Chandola et al., 2006). This is the body's natural way of avoiding a threatening situation. The parasympathetic system is the body's calming system and is stimulated by the ventral vagus nerve, which helps the body calm down and relax (Bjorntorp, 1991; Brunner et al., 2002; Chandola et al., 2006). "Basically, when humans feel safe, their nervous systems support the homeostatic functions of health, growth, and restoration, while they simultaneously become accessible to others without feeling or expressing threat and vulnerability" (Porges, 2022, p. 1). The body's evaluation of risk is commonly referred to as the Polyvagal Theory, which triggers the mind and body to respond unconsciously (Porges, 2022).

Biofeedback from an individual's heart rate variability (HRV) can help identify if the sympathetic nervous system (fight-flight-freeze) or the parasympathetic nervous system (rest and digest) is being activated and regulated by the heart rate (Zadina, 2023). For example, when someone is feeling frustrated, their HRV pattern, detected through biofeedback, becomes distorted and then activates a fight-flight-freeze response (Bjorntorp, 1991; Brunner et al., 2002; Chandola et al., 2006; Hibbs, 2007; Porges, 2022; Tyborowska et al., 2023; Zadina, 2023). Alternatively, if the individual experiences positive emotions, their HRV will stabilize, and the feedback will transmit information to the brain that elicits a more restful state (McCraty et al., 2016).

In a recent research study, Tyborowska et al. (2023) considered the fight, flight, and freeze response in their study of the amygdala's role (the brain's emotional center and potential marker for stress-resilience) during action-preparatory activities. The longitudinal experimental study in the Netherlands began five years before the COVID-19 pandemic with a sample of 17-year-old adolescents (*n* = 64) (Tyborowska et al.). The sample underwent fMRI-adapted "Go/No-go Under Threat" (GUNT) tasks (Tyborowska et al.). A threat-anticipatory freezing action and a transition to action were evoked to avoid a mild shock (Tyborowska et al.). The aversive stimulation was set to be unpleasant but not painful (Tyborowska et al.). The GUNT task quantified the participant's neural activity and physiological responses (relying on the mind and body connection) (Tyborowska et al.). The task was delivered using a PC Presentation software with participant view accessibility (Tyborowska et al.). In addition to the GUNT task, which yielded quantifiable data, the researchers used the Symptom Check List-90 Revised (SCL-90R) as a self-report measure of mental health functioning (Tyborowska et al.).

Additional surveys and scales were provided to parents to assess the participants' developmental history (Tyborowska et al.).

Tyborowska et al. (2023) recognized the heightened onset of affective disorders that often peak during adolescence and create vulnerability and resilience factors. Testing the adolescents' neural, physiological, and behavioral correlates aimed to predict potential resilient markers against the development of stress symptoms (Tyborowska et al.). Tyborowska et al. hypothesized that better separation of threat responses during adolescence may be a protective factor, specifically related to pervasive stress and uncertainty.

Overall, the goal of the reviewed research was to test whether action-preparatory threat responses in the brain's structure were linked to resilience or vulnerability to adverse effects of a pervasive stressor (the COVID-19 pandemic) (Tyborowska et al., 2023). Statistical analysis involved a paired sample *t*-test to examine the differences in reaction time between the high and low threat tails and a three-way repeated measures ANOVA with factors (high and low) and draw (shoot, withhold), and sex (boys, girls), with the alpha level set at $p < 0.5$ (Tyborowska et al.). Lastly, heart rate was also measured using finger clips, and changes in heart rate during the preparation period were calculated in beats per minute (Tyborowska et al.). Differences in heart rate responses were analyzed through a repeated measured analysis of variance (ANOVA) (Tyborowska et al.).

Researchers in the Tyborowska et al. (2023) study were presented with the rare opportunity to conduct their investigation of neural indicators of stressful events with the outbreak of the COVID-19 pandemic. The longitudinal study was validated and compared against previous research. The study found that adolescents demonstrated atypical patterns of lower amygdala activation for high-threat trials and higher amygdala activation for low-threat trials (Tyborowska et al.). This finding suggests that adolescents may have resilient factors during high-threat stress situations and may manifest vulnerability during lower-threat situations. Furthermore, this research indicated that adolescents showed fewer anxiety symptoms associated with resilience during heightened "action-preparatory" amygdala activity than compared to "threat anticipatory" activity (Tyborowska et al.). When anticipating a threat, adolescents engaged in "freezing" behaviors, which were linked to more internalizing symptoms of anxiety (Tyborowska et al.).

Given these findings, it may be suggested that adolescents showed more resilience during the pandemic (active threat); in contrast to post-pandemic, adolescents may be struggling with feelings of anticipation (of an upcoming threat) and, therefore, are showing more signs of anxiety. This research also helps to demonstrate why adolescents may be experiencing feelings of cognitive uncertainty and behavior paralysis (i.e., freeze) regarding academic motivation and school attendance. Students who are not motivated and do not possess metacognitive skills often fail to achieve high levels of self-regulation (Schraw et al., 2006).

Operant Conditioning Theory

The theoretical influence of operant conditioning is the most appropriate perspective on the mechanics upon which biofeedback was built and, therefore, a relevant theory to review for this study. In 1937, B. F. Skinner defined "operant conditioning" as behavior that affects the environment and is controlled by its consequences (Skinner, 1937; Staddon & Cerutti, 2003). The process of biofeedback originates in the behavioral principles of “shaping.” Shaping is the process by which one modifies his or her behavior as a result of positive reward or information feedback, thus increasing the likelihood that the behavior will reoccur (Staddon & Cerutti, 2003). Shaping is done through operant conditioning, which is also the mechanics of why biofeedback works (Thompson & Thompson, 2015).

Behaviors that are trained result in a series of learned responses that then lead to actions in the environment (Staddon & Cerutti, 2003; Thompson & Thompson, 2015). For example, if a person is not feeling well, he may take his temperature to determine if he has a fever. If the thermometer's feedback confirms a high temperature, he may take a fever-reducer medication. This change in action resulted in the feedback received from the thermometer and is a form of operant conditioning. This study engaged students in operant conditioning principles through heart rate variability (HRV) feedback. The students watched their HRV via a visual image with auditory sounds signaling a positive tone triggered by the rhythm of their heartbeat. The students were rewarded and reinforced by an upbeat sound, which then continued to shape the desired behavior (Demos, 2019). Behavior that is rewarded is likely to be repeated, whereas behavior that is punished will rarely occur (Demos, 2019). Skinner (1937) believed that operant behavior needed to involve a response that could be easily repeated. Moreover, the reinforcement of a behavior is likely to increase the likelihood of the behavior repeating (Demos, 2019; Staddon & Cerutti, 2003; Thompson & Thompson, 2015).

Biofeedback measures psychophysiological activity and follows the principles of operant conditioning. Learning new behavior through biofeedback training can be similar to learning how to ride a bike; the skills are never entirely gone once learned. However, regular practice may be warranted. This study wondered if the same may be true of learning self-regulation through biofeedback training and if the students could carry these learned skills into other areas of their lives. Operant behavior principles are also evident in the brain (Ripolles et al., 2014). When enjoyment is experienced, the brain secretes a neurotransmitter called dopamine. This brain-releasing chemical activates a reward pathway that motivates the brain with pleasure, increasing the likelihood that the person will engage in the behavior again (Ripolles et al.). This chemical reaction is an operant function of the brain and is how learning occurs. Research shows that learning can activate a dopaminergic reaction in the brain when learning brings enjoyment (Ripolles et al.).

Humans learn through positive and negative consequences (Skinner, 1938). However, if trained towards learning positive behaviors, students will have better outcomes (Ripolles et al., 2014). Biofeedback rewards healthy brain activity and increases the likelihood that behaviors of interest will repeat (Demos, 2019; Thompson & Thompson, 2015). Zadina (2023) discovered that learning moments that promote intrinsic satisfaction send similar reward signals to the brain that are more powerful and longer-lasting than extrinsic rewards. As such, increasing the reward center through intrinsic rewards during learning promotes positive emotions, and positive emotions promote HRV coherence. Operant conditioning changes behavior (Skinner, 1937; Thompson & Thompson, 2015). Skinner (1937) believed that the timing of the reinforcement is imperative for learning, which is why rewards should be closely given after the behavior occurs. Biofeedback operates similarly, with immediate reinforcement through auditory and visual feedback while the student engages in the preferred behavior.

Operant conditioning is closely tied to biofeedback, which believes that consequences follow behaviors that change future behavior (Demos, 2019; Staddon & Cerutti, 2003; Thompson & Thompson, 2015). Operant conditioning views human behavior as being shaped and controlled automatically and mechanically by environmental stimuli (Demos, 2019; Staddon & Cerutti, 2003; Thompson & Thompson, 2015). Research and literature on operant principles are paramount to student learning and thus support this study's use of biofeedback technology in schools.

Biofeedback Training in Schools

In reviewing literature and research on biofeedback training in schools, it was difficult to find recent research (within the past 10 years) connected explicitly to classroom learning. Most empirical studies on biofeedback training in school occurred between the 1960s and 2000s and involved a specific branch of biofeedback called neurofeedback. If biofeedback is the proverbial umbrella, neurofeedback is one of many types of biofeedback under that umbrella (Thompson & Thompson, 2015). Neurofeedback uses an electroencephalogram (EEG) biofeedback technology, providing feedback on brain wave activity. In contrast, biofeedback uses an electrocardiogram (ECG) and provides feedback on one's heart rate variability (HRV) (Thompson & Thompson, 2015). Biofeedback monitors measure the time between heartbeats (HeartMath Institute, 2018, 2020). Research on neurofeedback was spearheaded and influenced by the groundbreaking 1969 study by Sternman et al., which demonstrated for the first time that animals could be trained to produce brainwaves in the sensorimotor region of the brain. This discovery inspired research on biofeedback methods across clinical settings and educational institutions.

Behavior Regulation

One of the most impactful studies on biofeedback in education occurred from 1995 to 2001 and is commonly referred to in the field as "The Yonkers Project" (Carmody et al., 2000). The Yonkers Project was a neurofeedback program established in a public school in Yonkers, New York. Dr. Mary Jo Sabo and Vice Principal, Linda Vergara. obtained a grant to fund the neurofeedback equipment (Carmody et al., 2000). The Yonkers Project studied primary school students' brain waves in the classroom setting (Carmody et al., 2000). These measurements were derived from portable EEG technology that provided data on students' level of attention. The electroencephalogram (EEG) is a reliable measure of cognitive states and mental processes (Carmody et al., 2000; Thompson & Thompson, 2015). The Yonkers project aimed to provide neurofeedback training to a select group of students with the most challenging behavioral needs. The program successfully improved significant changes in impulsivity and hyperactivity for the students diagnosed with maladaptive behaviors (Carmody et al., 2000). The success of the biofeedback program led to its expansion to two additional schools in Yonkers, New York (Carmody et al., 2000). Unfortunately, funding for the program ended unexpectedly after the attacks on the city on September 11th, 2001.

Emotional Regulation

In 2023, a study was published that investigated the effects of biofeedback with elementary students addressing emotional regulation skills (Bearden et al., 2023). The study began in 2020 and was a repeated-measures (within-subject) design that involved a pretest/posttest HRV measurement from a total of 24 fifth-grade students (Bearden et al., 2023). There were three classroom visits and testing sessions (Bearden et al., 2023). The students participated in a 5-minute biofeedback activity (“Heart Lock-In” technique) daily (for 5-minute sessions) for 4 weeks (Bearden et al., 2023; HeartMath Institute, 2018). The first classroom visit was to collect baseline data, the second visit occurred after 4 weeks of receiving the biofeedback technique, and the third visit recorded the posttest data (each visit lasted approximately 3 hours) (Bearden et al., 2023). Mixed methods were used to get quantitative and qualitative data.

The researchers hypothesized that by practicing this technique, the students in the treatment group would have an increase in their resting heart rate compared to the control group who received a relaxation technique (Bearden et al., 2023). A univariate ANOVA confirmed their hypothesis (Bearden et al., 2023). “Students reported enhanced emotional stability, feeling more positive about themselves, and improved interpersonal relationships” (Bearden et al., 2023, p. 1). Students also reported better focus and academic performance (Bearden et al., 2023). The researchers championed their findings towards more awareness around social-emotional support in schools. They endorsed that schools are the most appropriate settings to provide the daily practice and routine to foster such skills (Bearden et al., 2023). The researchers concluded that the biofeedback benefits with emotional regulation may lead to other improvements in performance, such as academic success (Bearden et al., 2023; Bradley et al., 2007).

In August 2022 (Aranberri-Ruiz et al.), the International Journal of Environmental Research and Public Health published a study using a biofeedback intervention with primary school children who suffered from high levels of anxiety and stress. The goal was to reduce psychophysiological symptoms of stress using biofeedback. The study wanted to see if young students could learn conscious breathing techniques through biofeedback and reduce their symptoms of anxiety and stress. At a public primary school, a total of 585 students between 7 and 12 years of age (*M* = 8.51; *SD* = 1.26) participated in the study (Aranberri-Ruiz et al., 2022). A mixed design was used with two groups (treatment and control groups), two evaluative phases (pretest and posttest), and three “educational” cycles (Aranberri-Ruiz et al., 2022). The biofeedback technology used was called emWave (from HeartMath), and a standardized rating scale known as social-emotional assessment was used to measure the students' symptoms of anxiety and stress (Aranberri-Ruiz et al., 2022). The dependent variables were the high Heart Rate Variability (HRV) number and the anxiety and stress scores from the standardized assessment (Aranberri-Ruiz et al., 2022). The biofeedback intervention consisted of five individual sessions, with five HRV measures of data (Aranberri-Ruiz et al., 2022). “The applications from the HeartMath emWave program used to learn to breathe slowly and steadily were Balloon Game and Coherence Coach, where students learn to breathe at approximately six breaths per minute in a fun way” (Aranberri-Ruiz et al., 2022, p. 5). The breathing pattern that was taught during the biofeedback intervention (approximately six pairs of breaths per minute) has been recommended across many studies (Aranberri-Ruiz et al., 2022; Karavaev et al., 2013; Lin et al., 2020; Porges, 2022). “Breathing 6 times per minute activates the nucleus ambiguus, generating a less stressful emotional reaction and influencing the course of the emotional experience” (Aranberri-Ruiz et al., 2022, p. 2).

The intervention results yielded positive findings showing a reduction in levels of anxiety and stress. The study was analyzed using the Kolmogorov-Smirnov test and showed a normal distribution of the HRV data across the different cycles (Aranberri-Ruiz et al., 2022). An ANOVA test was used to analyze the standardized scores from the self-reports of anxiety and stress. The ANOVA was used for the blended design of 2 (group: treatment and control), 2 (pretest and posttest evaluation), and 3 educational cycles (Aranberri-Ruiz et al.). Finally, a Post Hoc comparison was conducted with the Bonferroni test. When taken together, the results were astoundingly significant for all measures of HRV, anxiety, and stress. The primary school students in the treatment group reduced all levels significantly, while the control group led to an unforeseen increase in anxiety and stress (Aranberri-Ruiz et al.). "Thus, we can conclude that the intervention not only improved anxiety and physiological and social stress numbers but also inverted the trend toward increased anxiety and social stress that occurred with the analyzed primary school student" (Aranberri-Ruiz et al., p. 8).

The researchers advocated that school systems are responsible for ensuring the psychosocial development of students and teaching the self-regulation skills needed to manage anxiety and social stress (Aranberri-Ruiz et al., 2022). Researchers of the study also acknowledged the lack of biofeedback interventions within the school context (Aranberri-Ruiz et al., 2022). A similar study in 2014 (Bothe et al.) shared similar results, thus supporting the efficacy of biofeedback intervention with primary school children and symptoms of anxiety. Aranberri-Ruiz et al. (2022) concluded their study with a critical consideration for future research. They noted that emotional regulation strategies are different among ages because of the developmental brain, calling attention to the brain's frontal region, which is responsible for executive functioning (Aranberri-Ruiz et al., 2022). Research showed associations between heart-rate variability training, increased emotional stability, and improved cognitive performance in primary school students (Bradley et al., 2010; Light & Bincy, 2016).

Cognitive Regulation

The study conducted by May et al. (2018) assessed the effectiveness of Heart Rate Variability Coherence Biofeedback Training compared to a high-intensity interval training protocol and a control condition. Unlike the previous studies involving primary school age, the 2018 study trained college students ($N = 90$) with biofeedback over a 4-week span (three sessions per week) with pre-post intervention assessments. The study measured "burnout effects" of depression and anxiety and its influences on cognition (a serial subtraction test) and physiology (a fitness test) (May et al., 2018). Findings for the HRV treatment group found a significant decrease in school burnout, an increase in mathematical performance, and a decrease in heart rate from pre- to post-intervention measurement (May et al., 2018). This study showed evidence that biofeedback training decreased burnout, improved aspects associated with cardiac health, and increased academic performance (May et al., 2018). Additional studies on biofeedback with college or university students found various benefits. In 2021, a study by Sha'ari and Amin found biofeedback benefits of increased feelings of resilience. In 2018, Sarwaria and Wahab discovered positive patterns in HRV with international postgraduate students.

In 2021, a quasi-experimental explanatory mixed methods study was conducted using an adolescent population and measured the effects of a biofeedback technique called "heart-focused breathing" (McLeod & Boyes, 2021). Two groups of adolescents (grades 9-12, *N* = 105) were formed into a treatment group and a control group. The treatment group practiced the technique for 50 minutes twice a week (McLeod & Boyes). Quantitative data were derived from standard surveys (Test Anxiety Survey, TAS; Students Opinion Survey-Short Form, SOS-SF) and a reading comprehension test (McLeod & Boyes). Results were analyzed by repeated–measures ANOVAs, which found increases in test-related self-efficacy, academic achievement, positive affect, and decreases in stress and worry (McLeod & Boyes). "Educational programs that incorporate social-emotional-learning (SEL) strategies, study skills, and mindful breathing using biofeedback can help adolescents decrease worry and social stress, increase test preparedness self-efficacy, and improve academic performance due to lowered levels of test anxiety" (McLeod & Boyes, p. 815).

Self-Regulation

In 2007, researchers at the Institute of HeartMath conducted the TestEdge National Demonstration Study at Claremont Graduate University, a two-part study investigating a multitude of self-regulation processes (Bradley et al., 2007). Although this study is more than 10 years old, its value to the field of biofeedback and education is important for review and is related to this study's focus on SRL. It also sheds light on the lack of current research related to biofeedback and self-regulated interventions in school.

The 2007 study was designed to investigate the TestEdge Program tailored for elementary and high school students. The first part was a quasi-experimental and a longitudinal field study that investigated students in the 10^{th} grade (at two high schools) using a pre-post intervention (Bradley et al., 2007). A total sample of students (*N* = 980) were divided by school, a treatment school (*N* = 636), and a control school (*N* = 344).

The 12-week program included approximately 12-15 brief (20-minute) lessons (depending on grade level) and was taught twice a week by teachers. Students learned to self-regulate their psychophysiological responses while taking tests. Quantitative and qualitative data were collected through survey questionnaires, interviews, structured observations, student work, and student state test scores (Bradley et al.). A sub-study from the primary study was then formed using a randomly stratified sample of students, and measured students' HRV (Bradley et al.). The purpose of the substudy (in a controlled laboratory setting) was to investigate further the degree to which students had learned the techniques taught to them in the TestEdge program (Bradley et al.). The study's findings showed that 75% of students from the treatment group had reduced levels of test anxiety. Data showed that students learned and used self-regulated strategies to overcome stress and test anxiety.

The secondary study investigated qualitative factors of program adherence, acceptability, and administration (Bradley et al., 2007). Results showed improved student standardized test scores, passing rates, and psychosocial functioning (Bradley et al.). The TestEdge program was created after 16 years of scientific research and taught students how to reduce stress and test anxiety through biofeedback technology (Bradley et al.). "Research has shown that psychophysiological coherence is characterized by increased synchronization in nervous system activity, increased emotional stability, and improved cognitive and task performance" (Bradley et al., p. 2). This study demonstrated the relationship between biofeedback and the application of SRL in education.

Self-Regulated Learning (SRL) in Education

Research on SRL is ample and positively correlates to student achievement (Azevedo & Cromley, 2004; Azevedo et al., 2004; Bannert et al., 2009; Broadbent & Poon, 2015; Nietfeld et al., 2006; Stark & Krause, 2009). Specifically, studies show that SRL interventions improve students' SRL skills and consequently improve students' overall performance on learning tasks (Azevedo & Cromley, 2004; Azevedo et al., 2004; Bannert et al., 2009; Broadbent & Poon, 2015; Nietfeld et al., 2006; Stark & Krause, 2009). Reviewed meta-analyses from Dignath and Buttner (2008), Jansen et al. (2019), and Theobald (2021) also showed that SRL strategies held a positive relationship with school outcomes and performance. Additionally, empirical research indicated that SRL declines within the first year of secondary education and with increasing grade levels, which supports the need for SRL interventions at the secondary level (Van der Veen & Peetsma, 2009; Schuitema et al., 2012). This should come as no surprise since academic learning in high school increases in difficulty alongside the magnitude of demands on executive functioning (Opdenakker, 2002). As such, SRL is an essential applied strategy for secondary students with further benefits to their cognitive and social functioning (Opdenakker, 2002).

In 2011, a study investigated the relationship between SRL and students' success in a distance learning program (Radovan, 2011). Findings from the study showed that SRL strategies were the key to better achievement outcomes: goal setting, the value of the task, self-efficacy, and effort regulation (Radovan, 2011). Research assumes that positive results may be due to students' engagement in SRL activities (Azevedo & Cromley, 2004; Azevedo et al., 2004; Bannert et al., 2009; Broadbent & Poon, 2015;

Nietfeld et al., 2006; Stark & Krause, 2009). Other studies on SRL showed that personality traits were indicative of SRL (specifically: agreeableness, conscientiousness, emotional stability, openness, sense of identity, optimism, tough-mindedness, work drive, and significant satisfaction (Bozpolat, 2016; Gupta & Mehtani, 2017; Kirwan et al., 2014). Factors of student effort and personality traits are important to consider during research implications.

A successful learner is someone who can regulate and control factors that influence their learning while motivating themselves, self-monitoring, and manipulating change as necessary (Gupta & Mehtani, 2017). These work habits are rooted in a self-regulated learner. Self-regulated students can identify distractions in their environments and remove themselves from these interferences (Gupta & Mehtani, 2017). In fact, SRL goes beyond learning academic content; it correspondingly involves modulating one's behavior. Gupta and Mehtani (2017) charge that SRL is a self-directed process that individuals take hold of and transform into successful learning outcomes. Self-regulated learners engage in learning through metacognitive, motivational, and behavioral processes (Gupta & Mehtani, 2017). Markedly, such active learners can self-generate their thoughts and feelings and apply action toward their goals (Zimmerman & Schunk, 2001).

Much of the educational research on SRL focuses greatly on the influences of cognitive functions and academic skills. The robust literature available illustrates the wide lens that self-regulation consumes in education and its importance in the learning process. The research reviewed on SRL addresses the value of teaching SRL skills in education while demonstrating the theoretical underpinnings of SRL (Bandura's Social

Cognitive Theory and Zimmerman's Self-Regulation Model) that highlight the direction of this study's approach.

Social Cognitive Theory

Learning takes on many forms, which social cognitive theory constitutes. The theory emphasizes the influence of several cognitive processes that are responsible for engagement in SRL. Unlike the operant behavior model, which views responses under the control of an external reward, cognitive theories explain learning through a brain-based learning approach (Bandura, 2001). Albert Bandura, psychologist and originator of social cognitive theory, challenged behaviorists with the idea that external outcomes do not solely regulate people; instead, people possess self-reflective capabilities that influence and control their thoughts, feelings, motivations, and behaviors (Bandura, 2001, 1991). Social cognitive theory explains that behavior change occurs due to the subfunctions of cognition (the process by which the brain's sensory input is transformed, reduced, elaborated, stored, recovered, and used) (Bandura, 1991, 2001, Raihan, 2011). For cognitive theorists, overall, human thought and learning are explained by how the brain processes information (Raihan, 2011).

Bandura's social cognitive theory of self-regulation believes that human behavior is motivated and regulated by self-influence (Bandura, 1991). Moreover, Bandura describes self-regulation as a self-reactive influence and a feature of human agency (Bandura, 2001). Social cognitive theory believes that individuals can make things happen by their own actions and agency. "Agency embodies the endowments, belief systems, self-regulatory capabilities, and distributed structures and function through which personal influence exercised, rather than residing as a discrete entity in a particular place" (Bandura, 2001, p. 2). Acts of agency are influenced by cognitive processes, environmental events, and brain development (Bandura, 2001). Social cognitive theory believes that individuals have a "functional consciousness" that has a purpose and takes deliberate action (2001). This emphasis on autonomous action aligns with the frameworks of SRL, which strives towards self-directed learning. Relatedly, brain development research also emphasizes "agency," or one's influential role, in how neural connections and functional structure are shaped (Sapolsky, 2018). Adolescents' premature brains are likely to struggle to engage in activities of goal setting and self-monitoring of thoughts and behaviors. This suggests that SRL assumes a major influence on cognitive and behavioral constructs, which SRL demands.

Above all, social cognitive theory and SRL consider that human behavior is regulated by self-influence (Bandura, 1991). "People form beliefs about what they can do, they anticipate the likely consequences of prospective actions, they set goals for themselves, and they otherwise plan courses of actions that are likely to produce desired outcomes" (Bandura, 1991, p. 248). Social cognitive theory views human forethought as the self-regulatory mechanisms that respond to incentives and guide actions (Bandura, 1991, 2001; Zadina, 2023). SRL operates under cognitive subfunctions, which illustrate the important role of self-observation, self-judgment, and self-reaction (Bandura, 1986, 1991).

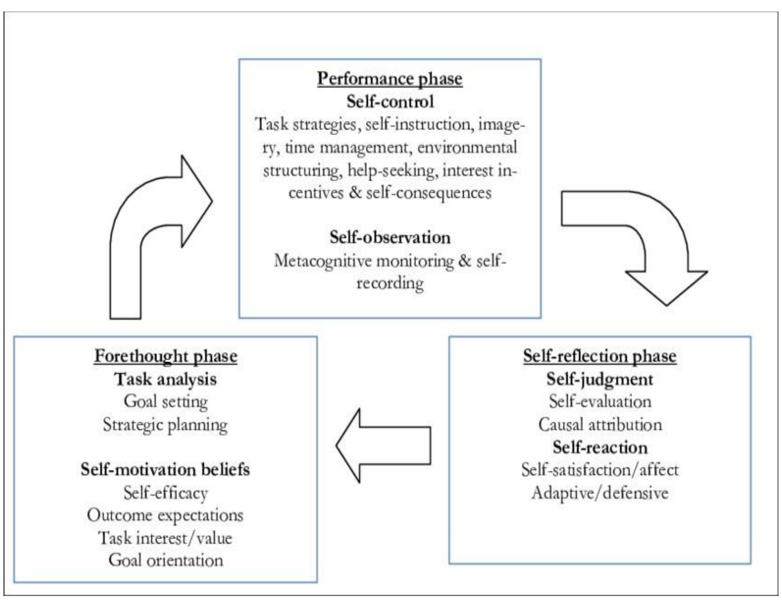
Self-Regulated Learning (SRL) Model

In school, educators are tasked with helping students learn intentionally, autonomously, and effectively. The fundamental goal of such pedagogy warrants the implementation of an SRL model in the classroom (Zimmerman, 2000). Across the many evaluative measures and frameworks for SRL reviewed, many popular inventories and well-established rating scales were developed and designed based on Zimmerman's theoretical model of SRL (Zimmerman, 2000). Zimmerman's model comes from social cognitive theory and Boekaerts' model (1999) and aligns with SRL behaviors intended for students.

Barry J. Zimmerman (educational researcher and professor) pioneered and developed one of the most comprehensive theoretical models of SRL (Panadero & Alonso-Tapia, 2014). The cyclical phase model was presented in 2000 (Panadero & Alonso-Tapia, 2014), modified over the years with the inclusion of the SRL process in 2003 (Zimmerman & Campillo, 2003), and revised in 2009 (Zimmerman & Moylan, 2009; see Figure 1). The review of current SRL research is organized into the three phases of Zimmerman's model: *forethought*, *performance*, and *self-reflection*. In each phase, students engage in different cognitive processes that activate SRL.

Figure 1

Zimmerman's Cyclical Model of SRL



Forethought Phase

During the *forethought* phase, self-regulated students first approach tasks by establishing goals and developing strategic plans (Zimmerman & Moylan, 2009). Two task analysis activities are performed in this phase: First, students need to analyze the task and decide how it should be performed, and then analyze the value of the task (Zimmerman & Moylan, 2009). Students ask themselves how the task will benefit their learning and then assign a value to the task, which increases motivation, effort, and attention (Zimmerman & Moylan, 2009). Research shows that students must value the activity before they can apply the effort needed to excel at the desired level (Panadero, 2017). As such, this phase activates and primes their SRL potential (Zimmerman & Moylan, 2009; Panadero, 2017). Students know the assessment criteria and standards of measurement alongside their work, and teachers pay critical attention to ensure that expectations are clearly explained (Panadero, 2017). Research supports positive effects on students learning when assessment criteria are presented (Andrade & Valtcheve, 2009; Jonsson, 2013; Panadero & Alonso-Tapia, 2014; Panadero & Jonsson, 2013). Next, students establish their goals and engage in strategic planning, which is an essential part of becoming a self-regulated learner. Zimmerman charges that planning and preparation are good predictors of success and help motivate students to set attainable goals (Pintrich, 2002; Zimmerman, 2008).

In 2019, a comprehensive meta-analysis was conducted to test the assumption that SRL interventions are effective in improving achievement due to the effects on students' engagement in SRL activities (Jansen et al., 2019). The study conducted a mediation analysis with meta-analytic data to determine if engagement in SRL activities was a significant mediator of the effect of SRL intervention on achievement. The researcher wanted to know what made SRL interventions effective (Jansen et al.). The study also addressed which characteristics influenced the effectiveness of SRL interventions (Jansen et al.). Several meta-analyses were used to determine the effect of SRL intervention on achievement, the effect of SRL intervention on SRL, and the relationship between engagement in SRL activities and achievement (Jansen et al.).

The population included students in higher education who engaged in SRL activities that specifically involved goal-setting and strategic planning opportunities (Jansen et al., 2019). A total of 395 effect sizes were extracted from 142 studies published in 126 articles, including peer-reviewed journals, conference proceedings, and dissertations (Jansen et al.). The average subsample size of the included effect size was $n = 124$ (Jansen et al.). Results discovered that SRL interventions effectively improved SRL activity and achievement; however, the variance of the effect sizes was not easily explained (Jansen et al.). The effects of the SRL intervention on achievement were deemed partially mediated by SRL activity. Most improvements from the SRL interventions for achievement were not due to improvements in SRL but instead due to other factors: motivation, cognitive activity, and time on task (Jansen et al.). Given these findings, the researchers recommended further analysis of the influence of these factors in relation to SRL (Jansen et al.).

Performance Phase

Performance and learning are active during this phase of Zimmerman's model. In the *performance* phase, self-regulated learners enable self-control and self-observation to assess their performance. Students self-monitor by observing their progress and making changes when necessary (Zimmerman & Moylan, 2009). During this phase, students are expected to maintain their focus and concentration by keeping track of their progress. By monitoring progress toward their set goals, students are likely to maintain or increase their motivation (Zimmerman & Moylan, 2009). Self-monitoring has been shown to improve student concentration, focus, and motivation (Van Loon & Oeri, 2023).

Self-regulated learners use metacognitive strategies during this phase to help them control the direction of their learning. Metacognitive strategies are the cognitive processes that students use to engage and understand their thinking about their learning process and regulate those processes that accelerate learning and memory (Ormond, 2020). When thinking about thinking (metacognition), students engage in self-instruction feedback that directs them toward their learning goals, thus demonstrating the cyclical model as a continuous learning process (Zimmerman & Moylan, 2009). Students provide themselves with feedback via metacognitive monitoring or are provided with incentive feedback received externally (i.e., teachers, peers, biofeedback, etc.). Feedback received during this phase prompts students to assess their performance efficiency and make decisions related to time management and self-management (Zimmerman & Moylan, 2009). Students need to allocate time for studying and monitor their on-task performance (Zimmerman & Moylan, 2009). This performance period is when students develop control of their learning, avoid distractions, and manage their on-task behavior **(**Corno, 1993). Research shows that learning success from high-achieving students utilize SRL strategies, whereas low-achieving students do not (Kosnin, 2007). Research also indicates that SRL can only be effective if self-monitoring is accurate, which is an important factor to consider in this study (De Bruin & Van Gog, 2012; Nelson & Narens, 1990).

A 2020 study in the Journal of Educational Psychology depicted similar metacognitive activities, with experimentation on self-monitoring accuracy and learning performance during self-regulated problem-solving (Mihalca & Mengelkamp, 2020). A total of 166 undergraduate students at a German university participated and were divided into two types of learning groups (full vs. restricted) and watched one of two historic learning videos (biography vs. laws of heredity) (Mihalca & Mengelkamp, 2020). Students were presented with a problem-solving task (questions about the heredity video), a prior knowledge test (questions regarding their prior knowledge of heredity laws), and a pretest and posttest (test to verify the success of the experimental manipulation of inducing prior knowledge) (Mihalca & Mengelkamp, 2020). Following the tasks, students were given a metacognitive task, which required them to judge the task's difficulty level (Mihalca & Mengelkamp, 2020; Striefel, 2001). The study used a 2 x 2 between-subjects factorial design, and results were statistically analyzed with confidence intervals for effect sizes using statistical software (Mihalca & Mengelkamp, 2020). The study aimed to determine the indirect effects of prior knowledge levels on performance by monitoring accuracy and learning from problem-solving tasks (Mihalca & Mengelkamp, 2020).

Results showed that students with prior knowledge monitored their performance more accurately than students who did not have prior knowledge (Mihalca & Mengelkamp, 2020). The study endorsed that “prior knowledge improves monitoring accuracy and performance because it provides the conceptual basis necessary for evaluating one’s performance and yields enough cognitive resources for performing the tasks and monitoring one’s performance simultaneously” (Mihalca & Mengelkamp, p.

805). The results were also supported by previous studies and consistent with theories of SRL (Mihalca & Mengelkamp). The researchers suggested that monitoring accuracy was a prerequisite for successful SRL and may be related to positive connections with cognitive processes and study time allocation (Mihalca & Mengelkamp). Additionally, this reviewed study was one of the only known studies that experimentally manipulated the effects of prior knowledge to monitor accuracy and gained credibility in the field for future research on the impact of self-monitoring (Mihalca & Mengelkamp).

Past research showed that self-monitoring holds more credence for high school students due to the increase in cognitive and academic demands placed on independent learning and control (Baars et al., 2018; Van Loon & Oeri, 2023). Reviewed studies confirmed this and emphasized that self-monitoring accuracy may be too young for children around the age of 10; however, by 12 years old, self-monitoring training has shown to be highly effective in predicting performance (Van Loon & Oeri, 2023). Accordingly, research indicated that adolescents have difficulties with self-monitoring, especially in learning problem-solving tasks in math and biology (Baars et al., 2018). Data explained that prerequisite academic skills are needed for successful SRL, which important factor to consider when comparing SRL and academic achievement. (Baars et al., 2018; Mihalca & Mengelkamp, 2020; Van Loon & Oeri, 2023).

Cook and Sayeski (2022) conducted a study with high school students using smartphones as self-monitoring tools in the classroom. Self-monitoring increased learning opportunities (such as on-task behavior) (Cook & Sayeski, 2022; Jansen et al., 2019). The smartphone with a vibrating application signaled high school students to self-monitor their on-task behaviors (Cook & Sayeski 2022). Results revealed moderate increases in on-task behaviors (Cook & Sayeski, 2022). Generalization across settings was not evident due to a small sample; however, teachers found the intervention acceptable for general education (Cook & Sayeski, 2022).

Self-Reflection Phase

During Zimmerman's phase of self-reflection, students evaluate their work and performance. Students make judgments on their work based on post-performance teacher feedback. Accuracy is important for prior tasks (like self-monitoring) and for students' responses to feedback (Kostons et al., 2012; Thiede et al., 2003). Zimmerman's SRL model promotes student autonomy throughout the learning process (Zimmerman & Moylan, 2009). Learning continues with self-evaluation through students' assessments of their goals and performance levels (Zimmerman & Moylan, 2009).

A two-part experimental study demonstrated features associated with the self-reflection phase of Zimmerman's model by investigating the impact of monitoring judgment through a process of "self-explaining" (Baars et al., 2018). A total of 82 secondary students between 12 and 15 years of age participated in the study and were randomly assigned to either the treatment (using the self-explanation condition) or the control group (Baars et al., 2018). The experiments were conducted in their classrooms using a computer program, with its first experiment using a pretest and posttest task (Baars et al., 2018). Students viewed an instructional video that modeled a problem in a step-by-step manner based on learning theories (Baars et al., 2018).

Students in the treatment condition had to explain the steps in the videos (Baars et al., 2018). Before beginning the "self-explaining" task, they were instructed on *how* to explain the steps in the problem-solving task and *why* they should use those steps (Baars et al., 2018). Students were then asked at the posttest to self-assess their performance to the set criteria (Baars et al., 2018). Self-explanations were coded using a system commonly used in previous research that formatted student types, principles, goals, and anticipative explanations (Baars et al., 2018; Chi et al., 1989). A repeated-measures ANOVA was performed, which found a consistent relationship between problem-solving complexity and self-monitoring (Baars et al., 2018). Although, self-assessments were reported to be inaccurate for the more complex problem-solving tasks (Baars et al., 2018). This study suggested that accurate monitoring and regulation seemed difficult for high school students when learning to solve complex problems (Baars et al., 2018; Butler et al., 1995).

An extension to the first experiment was conducted with slight differences in how students had to self-explain their learning process (Baars et al., 2018). The results from the first study predicted that the students may have experienced a cognitive load on their memory and, therefore, wanted to further measure the effects of students' mental effort (described as a basic feeling of workload) (Baars et al., 2018). The second study included a total of 60 secondary students (Baars et al., 2018). The procedure and method were similar to the first, except that the self-explaining task was given at a different moment, and mental effort was measured using a posttest scale (Baars et al., 2018). Results were derived by a repeated-measured ANOVA with a within-subject factor (pretest to posttest), and a between-subjects factor condition (treatment vs. control). Findings showed that a medium amount of mental effort was detected but with no statistical difference between conditions (Baars et al., 2018).

When taken together, both experiments in the study found that the quality of self-explanations mattered for monitoring accuracy and performance; however, monitoring did not improve for the students who self-explained when learning the problem-solving task (Baars et al., 2018). It is worth noting that the results of this study were inconsistent with those of the previous studies reviewed. For example, in the study by Griffin et al. (2008), self-explaining did not improve monitoring. Baars et al. (2018) claimed that differences in the results may be due to the cognitive demands of the different tasks. Particularly, it is possible that students can give better self-explanations about explanatory texts (Chi et al., 1989; Griffin et al., 2008) compared to texts that place demands on declarative and procedural knowledge (Baars et al., 2018). A similar study by Cho and Jonassen (2012) found learning benefits when students used self-explanations alongside an instructional explanation. The study explained how mental effort was linked to metacognitive accuracy (judgments based on a high level of cognitive processing) (Baars et al., 2018). Put simply, students demonstrated better accuracy in their self-monitoring when they were not feeling cognitively overloaded. The researchers confirmed this outcome with earlier studies and suggested that mental effort ratings were a cue for students' monitoring of their judgments (Baars et al., 2018). Past research reviewed consistently showed how students were different in their capacity to self-regulate, different in how they judged themselves, and different in levels of automaticity (Opdenakker, 2002; Winne, 2005; Zimmerman & Moylan, 2009). Collectively, this information supports how the mind's cognitive processes influence the body's physical responses to self-regulation.

Zimmerman’s self-reflection phase of SRL aimed to extract attributes of students’ successes and failures based on their task performance (Panadero, 2017). “An important potentially successful strategy for supporting students in monitoring and regulating their learning to solve problems is asking them to give self-explanations” (Baars et al., 2018, p. 579). The study advocated for future research related to self-explaining effectiveness when learning to solve problems and exploration of potential metacognitive processes that occur during learning (Baars et al., 2018; Cho & Jonassen, 2012; Griffin et al., 2008; Opdenakker, 2002). A takeaway from the self-reflection phase is that research confirmed that the quality of students’ reflections matters (Panadero, 2017; Panadero & Alonso-Tapis, 2014; Zimmerman & Moylan, 2009).

Zimmerman’s theoretical model of SRL is continuous because learning never ends. Zimmerman and Moylan (2009) explain that SRL is cyclical (forethought, performance, self-reflection) because the learning that takes place in one phase builds upon the next phase. What the students experience and how they interpret their successes or failures influences their future motivations (Dweck, 2008). “Suddenly we realized that there were *two* meanings to ability, not one: a fixed ability that needs to be proven, and a changeable ability that can be developed through learning” (Dweck, 2008, p.15). Through the process of self-reflection, if students believe they failed, they become defensive and negative and view their future through a “fixed mindset,” with fewer possibilities for success (Dweck, 2008). Whereas, if students failed but responded with more adaptive and optimistic remarks for future choices, then they are more inclined to maintain learning and success through a “growth mindset,” which reinforces the likelihood of future SRL behaviors (Dweck, 2008; Zimmerman & Moylan, 2009).

Time To Learn (TTL)

While the pandemic was unexpected, and a certain degree of trauma and stress was expected, it is clear that many students did not have the tools to be resilient at the time of adversity to return and stay in the classroom (Schunk & Zimmerman, 1994). Time spent in the classroom learning matters and is meaningful to student outcomes (Farbman, 2015; Hoxby & Murarka, 2008). In general, more time in the classroom assumes that more instruction is delivered and more learning is received, thus increasing student performance and academic success (Borg, 1980; Brown & Saks, 1986; Cotton & Savard, 1981; Farbman, 2015).

Connecting time to learning was first highlighted in 1963 by the work of John Carroll, who explored quantifying time to "degrees of learning" through a conceptual framework (Farbman, 2015). Carroll's theory charged that more time spent in a productive learning environment would increase academic proficiency (Farbman, 2015). Studies have continued to explore Carroll's work on the relationship between time allocated to learning and academic success, yet the research reviewed seemed limited to after-school programming and extended school year.

Time is a core variable in learning, which makes it essential for educational research; however, the term differs greatly in defining criteria (Farbman, 2015). Past researched showed that time can be interpreted as time on task, active engagement, task completion time, time to achieve mastery learning, and learning rate time (Schunk & Zimmerman, 1994). Despite the exhaustive operational indices of time, this current study plans to study the percentage of time all students are together in class in the presence of learning instruction (Gettinger & White, 1979) and will be referred to hereinafter as Time To Learn (TTL).

The literature reviewed showed that time in the classroom plays a role in learning, with reported increases in learning opportunities and increased achievement (Borg, 1980; Brown & Saks, 1986; Cotton & Savard, 1981; Dynaski et al., 2004; Frazier & Morrison, 1998; Lauer et al., 2006). Studies also indicated connections between time and SRL activity (Cook & Sayeski, 2022; Jansen et al., 2019). The National Association of School Psychologist's Daily Digest (January 2024), along with the local teachers from this study, expressed concerns with the amount of time students leave the classroom (i.e., skipping class, long bathroom breaks, nurse visits, guidance counselor visits, doctor's appointments, etc.). Consequently, the literature reviewed supports TTL as one of the intended foci of the study.

Summary

In the final review, biofeedback training interventions, SRL in education, and TTL have clear crossover responsibilities and purposes in educational psychology and in this study. The analysis of psychophysiological foundations and operant conditioning roots of biofeedback provides a vast understanding of how adolescents may unconsciously respond to their environment when dysregulated (Zimmerman & Moylan, 2009). Research on biofeedback training in schools found a wide range of benefits related to SRL and improved academic performance (Aranberri-Ruiz et al., 2022; Bearden et al., 2023; Bjorntorp, 1991; Bothe et al., 2014; Bradley et al., 2007, 2010; Brunner et al., 2002; Carmody et al., 2000; Chandola et al, 2006; Christodoulou & Black, 2020; Chu et al., 2020; Frank, 2023; HeartMath Institute, 2018, 2020; Light & Bincy, 2016; May et al., 2018; McCraty et al., 2016; McLeod & Boyes, 2021); Peper & Shaffer, 2018; Porges, 2022; PWEBS, 2023; Russo et al., 2020; Sattar & Valdiya, 1999; Thompson & Thompson, 2015; Tyborowska et al., 2023; Winne & Perry, 2000; Zadina, 2023).

Research showed how teachers are struggling with the short attention spans of their students, making teaching more challenging, and SRL interventions all that more valuable (Alvarez, 2023; Brozovich et al., 2021; Calma-Birling & Zelazo, 2022; Cook & Sayeski, 2022; Drysdale, 2023; Lessard & Puhl, 2021; Scott et al., 2021; Theobald, 2021; Van Loon & Oeri, 2023; Walker, 2023; Weir, 2023; Zadina, 2023). Self-regulated learners take control of their learning by setting goals, creating plans, and self-monitoring, which are processes influenced by the theoretical models of social cognitive theory and Zimmerman's SRL model (Bandura, 2001; Pintrich, 2000; Zimmerman & Moylan, 2009). Above all, research showed that SRL is critical in the field of education, as it can enable students to learn more effectively and maximize their learning and potential (Aranberri-Ruiz et al., 2022; Bearden et al., 2023; Bjorntorp, 1991; Bothe et al., 2014; Bradley et al., 2007, 2010; Brunner et al., 2002; Carmody et al., 2000; Chandola et al, 2006; Frank, 2023; HeartMath Institute, 2018, 2020; Light & Bincy, 2016; May et al., 2018; McCraty et al., 2016; McLeod & Boyes, 2021; Peper & Shaffer, 2018; Porges, 2022; PWEBS, 2023; Russo et al., 2020; Sattar & Valdiya, 1999; Thompson & Thompson, 2015; Tyborowska et al., 2023; Zadina, 2023).

Furthermore, research showed that time spent in the classroom is meaningful and provides more opportunities for learning instruction, thus achieving academic success (Borg, 1980; Brown & Saks, 1986; Cotton & Savard, 1981; Farbman, 2015). Several studies have established the importance of SRL for success in school and in future life;

however, research has yet to clarify the role biofeedback has as a potential SRL strategy for adolescent students (Artuch-Garde et al., 2017; Chu et al., 2020; Dent & Koenka, 2016; Jansen et al., 2019; Theobald, 2021; Venitz & Perels, 2018; Zimmerman, 1990).

CHAPTER THREE

Methodology

Overview of the Study

The study employed a 6-week evidence-based intervention of biofeedback training as an in-classroom SRL strategy in a public secondary school in the northeast region of Massachusetts. The plan investigated SRL (using a pretest/posttest method) and TTL (using percentages of time data) differences between a Treatment Group (TG) and a Control Group (CG). The empirical method used a univariate procedure examining one dependent variable at a time. The intended participants were students in their sophomore year of high school (ages 15, 16, and 17), enrolled in the same section of a co-taught English class with the same two teachers providing instruction. The designed study operated under a quasi-experimental research method, which resembled experimental research but was not a true experiment due to the inability to collect data from a randomized sample. Due to the nature of the study's intention to implement a classroom-wide intervention, a convenient sampling procedure was used with pre-established classroom groups. At the conclusion of the study, the CG was offered an opportunity to receive biofeedback intervention if the results were deemed favorable.

Research Methods

Participants

The total adolescent sample ($N = 30$) was divided evenly into the TG ($n = 15$) and CG ($n = 15$), with students ages 15, 16, and 17. Students were selected via convenient sampling due to the pre-established classroom assignments. All student participants were in their sophomore year of high school and enrolled in the required English course for graduation. The public secondary school that the participants attended was in a suburban town in the northeast of Massachusetts.

Human Subjects

The study worked with human subjects; therefore, special attention was considered to meet the requirements set forth by California Coast University (CCU) and the United States Department of Health and Human Services (HHS) as detailed in 45 CFR46-Subpart A, known as the "Common Rule." The study aimed to follow "exempt" practices with human subjects by continuously demonstrating ethical practices that ensure safety and respect to the youth by the following exempt criteria: 1) Research was conducted in an established public educational setting that adhered to standard educational practices that would not likely adversely impact students' opportunity to learn. Specially designed instruction continued to be provided to students who were entitled via their educational plans. 2) Research would only include interactions with participants involving a visual demonstration of how to operate the technology, use of a tracking sheet, and questionnaire inventory. All information obtained was recorded using a student ID system, ensuring that all participants' identities remained confidential. There were no disclosures of participants' responses outside of the research. 3) The biofeedback intervention was brief (under 5 minutes) and safe. Parent *consents* and participant *assent* forms were provided with scientific evidence on the value of biofeedback as a safe mind-body technique (see Appendix C). The intervention can be considered a benign behavioral intervention similar to an online game. The intervention was viewed individually on each student's iPad. Students had access to earbuds that would allow for a more private experience. 4) Students were informed of the nature and purpose of the research without revealing the specific, measurable data points collected (i.e., the percentage of time they leave the classroom), with the purpose of protecting the study's construct validity from extraneous influences. 5) Parent/guardian *consent* forms were issued in addition to participant *assent* forms. Participants were explicitly informed that the data collected would only be used for research purposes, that their participation was entirely voluntary and optional, and that they could withdraw from the study at any time during the data collection process. 6) While unlikely needed (given the benign nature of the study), nonetheless, participants were informed and reminded of all safeguards and protections available to them (and for all students) provided by the school (individual school-based counseling and family guidance support). 7) Information was provided to all parties regarding the common use of biofeedback currently experienced every day as a relatable technique. For example, most Apple Watches measure heart rates and physical activity that trigger popups to help change one's behavior (i.e., "Time to Stand"). Biofeedback can also be reflected in the use of a thermometer showing a high temperature, alerting the person to act upon that feedback information. 8) Lastly, the technology was securely locked in a closed mobile charging cart that was stored in a personal locked office space.

Instruments

The HeartMath Inner Balance Application and Sensor

The Inner Balance biofeedback tool from HeartMath is designed to help students achieve a collective focus, which is an essential characteristic of SRL (see Appendix D). The sensor is a safe ear clip that is secured to the ear lobe with soft padded supports (similar to how a "clip-on earring" attaches to the ear). The other end of the sensor is plugged into an iPad and activates once the Inner Balance App is open. When the App is selected to begin a session, the sensor will start to calibrate real-time heart rhythms on a visual display. The App will provide visual and auditory feedback to help guide the student to achieve better focus by providing breathing techniques and mindful strategies that can positively modify the heart rhythm in real-time for better efficiency. Robust research studies are available on HeartMath techniques in education and their implications on academic performance (Frank, 2023).

The Motivated Strategies for Learning Questionnaire (MSLQ); Metacognitive Self-Regulation (MSR) Subscale.

The Motivated Strategies for Learning Questionnaire (MSLQ) is an 81-item self-report questionnaire and is comprised of two major sections: Learning Strategies and Motivation (Pintrich et al., 1993; see Appendix E). MSLQ contains 15 different scales that are modular for convenience by administering the scales either together or individually for targeted areas of measurement or study (Pintrich, 1991). The individual-scaled tests are also designed for student group administration. The MSLQ instrument was developed on the theoretical foundation of the three phases of self-regulated learning by Zimmerman (2000), which most appropriately aligned with the intervention of this study.

The Motivated Strategies for Learning Questionnaire (MSLQ) was designed based on a cognitive view of motivation and learning strategies. Many contributors helped establish the theoretical framework that originally created the instrument (McKeachie et al., 1986; Pintrich, 1988a, b; 1989; Pintrich & Garcia, 1991; Pintrich & DeGroot, 1990). MSLQ was originally developed in 1986 and administered to college students. After years of data analysis and empirical studies, the MSLQ was updated and revised. The Cronbach's alphas are robust, ranging from .52 to .93 (Ilker, 2014; Pintrich et al., 1993). The MSLQ shows reasonable factor validity and reliability (Ilker, 2014; Pintrich et al., 1993). The MSLQ is widely used and the most established assessment instrument for SRL with reasonable correlation statistics with academic performance (Pintrich et al., 1993; Roth et al., 2016). Research that has used the MSLQ upholds that the reliability and validity of the instrument have confirmed that it measures the same construct over time (Schuitema et al., 2016; Van de Veen & Peetsma, 2009).

This study used the *Metacognitive Self-Regulation (MSR)* subscale questionnaire under the learning strategies section of the MSLQ (see Appendix F). The MSR contains 12 items that are prepared in accordance with a 7-point Likert-type scale. The items range from "1 = not at all true of me" to "7 = very true of me." Students were asked to find the number between 1 and 7 that best described them. The MSR subscale measured three general processes of metacognitive self-regulatory activities (Pintrich et al., 1993). These activities included *planning*, *monitoring*, and *regulating*. These areas of measurement were consistent with Zimmerman's cyclical phases and the purpose of this current study. Planning activities help to prime for SRL through goal setting and task analysis (Zimmerman & Moylan, 2009). Aspects of prior knowledge are then organized, making comprehending the material easier (Zimmerman & Moylan, 2009). Monitoring activities help to sustain attention, and regulating activities guide the adjustment of one's behavior as needed (Zimmerman & Moylan, 2009). The MSR measured SRL by assessing these three general processes of metacognitive self-regulation and applying the theoretical analysis of the social cognitive theory framework. Consequently, the instrumentation of the MSR with the biofeedback intervention was chosen and implemented with the three self-regulatory processes in mind.

The MSR subscale assessment was scored by calculating the mean of the items that make up the scale (Pintrich et al., 1993). For example, the MSR has 12 items; the student's score for MSR would be computed by summing the 12 items and taking the average. Items that were coded as "reverse" items (negatively worded items) must be reversed before scoring (Pintrich et al., 1993). For example, if the student selected a 1 for that item, then received a 7 for that item, thus scoring for the positive version of the question. The MSR questionnaire was administered to all students via a Google Form as a pretest and posttest data collection method.

Procedures

Consents & Assents

Formal permissions, consent, and assent forms from the school district's administrators, teachers, parents, and students were obtained to ensure that all participants and stakeholders were informed of the research study's purpose and procedures and that confidentiality measures were in place. Institution consent was received, allowing the study to take place at the secondary school during the allotted time period between February and April school vacations (see Appendix G). Participant consents were received from parents and teachers, and assent forms were received from students. The two teacher participants provided consent and informed understanding of their participation by allowing the study to take place in their classroom for the allotted time and agreed with the study's confidentiality and protection of students' identities. Parent consents were received, allowing their adolescent to participate in the study and providing or denying consent on the use of photography. Student assent forms were received and created with similar information from the parent consent forms.

Forethought Phase

Before the implementation of the 6-week intervention, *all* students completed the MSR pretest questionnaire. This information was used as baseline data to measure SRL. Pretest data were pulled together, and summed totals were stored using Google Sheets and Excel documents.

Directly following, the TG received a training workshop (during 2 class periods) on how to use the biofeedback technology (see Appendix H). The demonstration opportunity aligned with the preparation process of SRL, which research supported as a critical indicator of students' success (Pintrich, 2002; Zimmerman, 2008). It was important for the students to be familiar with the instrument prior to the intervention to ensure the integrity and validity of the study. The goal of this first phase (Zimmerman's forethought phase) was to prepare the students with a demonstration of the intended value of the task and model clear task instructions and procedures (Zimmerman & Moylan, 2009).

The CG continued to receive their regularly planned English instruction for the entirety of the intervention period. All student participants met for their English class 3-days out of the week at varying times. Both groups received the same curriculum and lesson plans, with the only difference being the TG's receipt of the targeted biofeedback intervention.

An established check-in/check-out system (i.e., hall passes) was already in place prior to this study, which was used for data collection on TTL and referenced in later analysis. The hall pass system required students to receive signed teacher signatures and time stamps for when they left and returned to the classroom. All student participants used the same classroom check-in/check-out system (i.e., bathroom, nurse, check-in with a guidance counselor, going for a walk, getting water, etc.). The standing classroom rule was that no more than one student was allowed to leave at a time.

Performance Phase

The TG engaged in a brief biofeedback intervention 3 times a week for 6- weeks at the beginning of their English class, prior to formal learning instruction. TG students were expected to independently initiate the task by retrieving their equipment at the start of the class, returning to their desks, and independently beginning their 5-minute biofeedback session.

All students in the TG had an assigned iPad and an Inner Balance HeartMath ear clip. Students were provided with Bluetooth-capable earbuds to ensure a private experience with their personal auditory feedback. First, students secured their ear clip to their earlobe (it did not matter which one but were instructed to maintain consistency by using the same earlobe throughout the study) and then plugged the other end into their iPad. Next, the students inserted their earbuds into their ears and turned on the Inner Balance App on their iPads, which then began to calibrate their HRV.

Students viewed their HRV via a real-time trend line and a “Mandala” (a pulsating circle) on the screen that demonstrated a pulse or pattern like how one should optimally breathe in and out. This pattern helped to promote coherence (a stable and regular rhythm) by practicing the “heart-focused breathing” technique (HeartMath Institute, 2018) that was taught to them during the forethought phase. The Mandala lit up in sections along the circular path, providing the students with positive reinforcement (feedback) as they engaged in paced breathing. *Green* demonstrated coherence, *Blue* prompted feedback of positive reinforcement to direct the student to return to coherence, and *Red* signified that the student was out of coherence.

Students were rewarded with delightful sounds when in coherence and reinforced with positive messages under the Mandala to help teach them to stabilize their breathing patterns. The imagery of pulsated breathing helped them to focus on what they needed to be doing to match the breathing. This process of self-monitoring and observing parallels with Zimmerman's performance phase and the importance of progress tracking (Zimmerman & Moylan, 2009). Pleasant images and sounds were intended to keep students' interest, motivate positive behaviors, and provide helpful feedback toward their goals (HeartMath Institute, 2018; Panadero & Alonso-Tapia, 2014; Skinner, 1937; Thompson & Thompson, 2015; Zimmerman & Moylan, 2009).

The TG independently engaged in the biofeedback activity for 5 minutes. The scheduled time was programmed in the system during the training process, which then allowed the session to automatically stop the session when finished. Once complete, the students filled out a Student Tracker Worksheet, aligning with the SRL model of self-monitoring and self-evaluation (Cook & Sayeski 2022; HeartMath Institute, 2024; Mihalca & Mengelkamp, 2020; Van Loon & Oeri, 2023; Zimmerman & Moylan, 2009; see Appendix I). Students logged the length of time spent on the task, their level, their average coherence score, and their achievement points earned. Lastly, they wrote a short goal (called a Coherence Challenge), sharing when and where they would plan on applying the breathing strategy to a specific situation. Students were also able to view their progress on the Inner Balance App, which kept a record of their performance and goals over time. Zimmerman's model values goal setting at the initial phase, as well as the importance of tracking and monitoring goals during the performance phase (Zimmerman & Moylan, 2009).

Self-Reflection Phase

After the 6-week intervention period, *all* students were administered the MSR posttest questionnaire. The posttest was delivered to all participants via a Google Form on the final day of the intervention. Posttest data were pulled together, and summed totals were stored on Google Sheets and Excel documents. This was the final procedure for data collection on SRL.

The second dependent variable, TTL, was measured by the percentage of time that *all* students were together in class receiving learning instruction. These data were derived from the check-in/check-out system during the intervention period and stored in Excel documents. This was the final procedural step for data collection on TTL.

Treatment Fidelity

To ensure treatment fidelity and that the biofeedback intervention was conducted as intended by the designed research, the following safeguards were implemented:

Teachers participated in the training process alongside their students. This helped to provide them with equal access to knowledge of the equipment and an opportunity for rapport and buy-in with the study's purpose. Teachers were also offered weekly check-in times with the researcher to communicate any noteworthy occurrences or concerns. Following the completion of the study, all student participants were given an opportunity to debrief about their experience and provide written feedback (see Appendix J).

CHAPTER FOUR

Results

The results of the study used comprehensive research designs and data analysis, with illustrated tables and figures. The findings are organized as follows: a description of the sample, RQ1 results from the MSR pretest and posttest between group data, RQ2 results from the TTL data analysis, and closing with post-hoc data analysis considerations.

Description of the Sample

The population from the present study were high school students (ages 15, 16, and 17) enrolled in a sophomore-year English class in a suburban town in the northeast of Massachusetts. The sample size consisted of 30 students, split evenly (15/15) between two classroom sections of sophomore English, taught by the same two teachers (one male general educator and one female special educator). The sample of students ($N = 30$) was selected via convenient sampling due to the pre-established classroom assignments, and the classroom groups were randomly assigned into a Treatment Group (TG) and a Control Group (CG). Table 1 represents the distribution of student participants via frequencies and percentages.

Table 1

Frequency Table for Nominal Variables

	Group	
Variable	Treatment	Control
Gender		
Female	5 (33.33%)	8 (53.33%)
Male	10 (66.67%)	7 (46.67%)
Missing[a]	0 (0.00%)	0 (0.00%)
Total	15 (100.00%)	15 (100.00%)

"table continues"

Variable	Group: Treatment	Group: Control
Ethnicity[b]		
White	9 (60.00%)	12 (80.00%)
Hispanic or Latino	2 (13.33%)	1 (6.67%)
Asian	1 (6.67%)	2 (13.33%)
Black	3 (20.00%)	0 (0.00%)
Educational Plan		
Gen Ed[c]	9 (60.00%)	4 (26.67%)
Ed Plan[d]	6 (40.00%)	11 (73.33%)
Missing	0 (0.00%)	0 (0.00%)
Total	15 (100.00%)	15 (100.00%)
ELL[e]		
ELL	1 (6.67%)	0 (0.00%)
Non-ELL	14 (93.33%)	15 (100.00%)
Missing	0 (0.00%)	0 (0.00%)
Total	15 (100.00%)	15 (100.00%)

Note. Due to rounding error, percentages may not sum to 100%.

a. Missing= Student withdrew from school.

b. Ethnicity= Ethnicity categories reported by the school district.

c. Gen Ed= Students receiving general education.

d. Ed Plan= Students supported by educational plans (i.e., Individualized Education Plans or 504 Educational Accommodation Plans).

e. ELL= English Language Learner

Frequencies and Percentages

The TG had the most frequency under the Gender category for Male (n = 10, 66.67%) with the remaining frequencies for Female (n = 5, 33%); indicating that the majority of students in the TG were male. TG demographics under Ethnicity were represented by the majority of students falling under the category White (n = 9, 60%) with the remaining ethnicities Hispanic or Latino (n = 2, 13%), Asian (n = 1, 7%), and Black (n = 3, 20%). The majority of the TG were comprised of Gen Ed students (n = 9, 60%), with the remaining students falling under Ed Plan (n = 6, 40%). One student in the

TG fell under the ELL category (*n*=1, 7%) and had access to support. During the study, the student did not require or access additional support.

The CG was almost evenly separated by Gender, with frequencies for Female (*n* = 8, 53%) and Male (*n* = 7, 47%). CG demographics under Ethnicity were represented by the majority of students falling under the category White (*n* = 12, 80%), with the remaining ethnicities Hispanic or Latino (*n* = 1, 7%), Asian (*n* = 2, 13%), and Black (*n* = 0, 0.00%). Unlike the TG, the majority of the CG were comprised of students on Ed Plans (*n* = 11, 73%), with the remaining students receiving Gen Ed (*n* = 4, 27%).

Attrition

Midway through the study, a student in the CG withdrew from school and all school-related activities. As such, sample size values were adjusted according to the measurement criteria related to the targeted research question. For RQ1, the missing student was not available to complete the posttest. Therefore, results would not yield meaningful data if included, and therefore, for RQ1, the sample size was adjusted to 14 students. For RQ2, the intended nature of the question and the constructed value of TTL deemed the missing student data relevant to include. Therefore, the sample size data remained at 15 students.

Research Question #1

RQ1: Is there a significant difference in *Self-Regulated Learning (SRL)* among the students who received the biofeedback intervention compared to those who did not?

Data were scored and computed using analysis methods in the Data Analysis Toolpack by Excel. A pretest/posttest research design was delivered to the TG and CG. Participants in each group were assessed at two time periods: pretest (first week) and posttest (last week). Participants were treated the same in their respective groups. The TG received 6 weeks of the biofeedback intervention, while the students in the CG did not. To answer RQ1, three statistical tests were performed. All statistical measures used 2-tailed *t*-tests to analyze the possibility of differences in both directions.

Table 2

Frequency Table for MSR Pre and Post Change

	Group	
Variable	Treatment	Control
Change Between Pre and Post		
IMPROVED	6 (40.00%)	9 (64.28%)
DECREASED	7 (46.67%)	4 (28.57%)
NO CHANGE	2 (13.33%)	1 (7.14%)
Missing[a]	*0 (0.00%)*	*1 (7.14%)*
Total	15 (100.00%)	14[b] (100.00%)

a. Missing= Student withdrew from school.

b. CG percentage values were calculated using a total sample size of 14 students.

The TG revealed that out of a sample of 15 students, 40% of students improved on their pre and post scores, while 47% decreased in pre and post scores. Additionally, 13% of students from the TG underwent no change in their pre and post total performance. Alternatively, the CG demonstrated the most positive change in their pre and post scores, with 64% of students showing improvement. Only 29% of students decreased in the pre post performance, and 7% of the group had no change.

First, a paired samples *t*-test was conducted on pre and post differences for the TG.

Table 3

TG: Paired Samples Statistics

	Mean	N	Std. Deviation	Std. Error Mean
PreTotal	48.0667	15	12.03843	3.10831
PostTotal	48.7333	15	11.12569	2.87264

Table 4

TG: Paired Samples Test Paired Differences

	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper	t	df	Significance One-Sided p	Significance Two-Sided p
PreTotal-PostTotal	-.67	6.54	1.69	-4.30	2.96	-.40	14	.350	.699

The results of the paired samples *t*-test for the TG were not statistically significant ($t(14) = -.40$, $p = .699$), indicating that there was no significant change in MSR scores between the pretest and posttest among student participants in the TG.

Table 5

TG: Paired Samples Effect Sizes

		Standardizer[a]	Point Estimate	95% Confidence Interval Lower	95% Confidence Interval Upper
	Cohen's d	6.54	-.102	-.608	.407
PreTotal- PostTotal	Hedges'g	6.92	-.096	-.574	.385

a. The denominator used in estimating the effect sizes

Analysis of Cohen's *d* and Hedges' *g* were used to measure the size of the difference (effect size) between pre and post total averages for the TG. Cohen's *d* used the sample deviation of the mean difference, which yielded a small effect size ($d = -.102$). Hedges' *g* is commonly used for small sample sizes (<20) and was included as part of a comparative analysis. The results of Hedges' *g* used the sample standard deviation of the mean difference, plus a correction factor and also found a small effect size ($g = -.096$).

Next, a paired samples *t*-test was performed on pre and post differences for the CG.

Table 6

CG: Paired Samples Statistics

	Mean	N	Std. Deviation	Std. Error Mean
PreTotal	47.8571	14	13.28885	3.55159
PostTotal	51.7143	14	10.38067	2.77435

Table 7

CG: Paired Samples Test Paired Differences

		Std.	Std. Error	95% Confidence Interval of the Difference				Significance	
	Mean	Deviation	Mean	Lower	Upper	t	df	One-Sided p	Two-Sided p
PreTotal-PostTotal	-3.86	10.80	2.89	-10.10	2.38	-1.34	13	.102	.204

The results from the paired samples *t*-test for the CG were not statistically significant ($t(13) = -1.34$, $p = .204$), indicating that there was no significant change in MSR scores among the student participants in the CG between the pretest and posttest.

Table 8

CG: Paired Samples Effect Sizes

				95% Confidence Interval	
		Standardizer[a]	Point Estimate	Lower	Upper
	Cohen's d	10.80	-.357	-.892	.190
PreTotal- PostTotal	Hedges'g	11.48	-.336	-.839	.179

a. The denominator used in estimating the effect sizes

Analysis of Cohen's *d* and Hedges' *g* were used to measure the size of the difference (effect size) between pre and post total averages for the CG. Cohen's *d* used the sample deviation of the mean difference, which yielded a small effect size ($d = -.357$). As noted, Hedges' *g* is commonly used for small sample sizes (<20) and was included as part of a comparative analysis. The results of Hedges' *g* used the sample standard deviation of the mean difference, plus a correction factor, and also found a small effect size (*g*= -.336).

Finally, an independent samples *t*-test was conducted to measure the pre and post changes between the TG and CG. The change was computed by posttest MSR scores minus pretest MSR scores.

Table 9

TG & CG: MSR Difference Statistics

	Mean	N	Std. Deviation	Std. Error Mean
Treatment	.67	15	6.54	1.69
Control	3.86	14	10.80	2.89

Table 10

TG & CG: Independent Samples Test MSR Differences

	t-test for Equality of Means		Levene's Test for Equality of Variance		95% Confidence Interval of the Difference				Significance	
	Mean Difference	Std.Err Difference	F	Sig	Lower	Upper	t	df	One-Sided p	Two-Sided p
Equal Variances Assumed	-3.190	3.29	1.055	.313	-9.94	3.56	-.97	27	.170	.341
Equal Variances Not Assumed	-3.19	3.34			-10.14	3.76	-.954	21	.175	.351

Results from the CG revealed a larger mean change in MSR pre and post averages (*m* = 3.86) than compared to the average measured change for the TG (*m* = .67).

For the independent samples *t*-test, a Levene's test was used to verify the equality of variances assumption. The assumption was supported by the non-significant finding from the Levene's test (p = .313). In other words, equal variances were assumed based on homogeneity of variance between the two groups. Moreover, the independent samples t-test was not statistically significant, $t(27) = -0.97$, $p = .341$, indicating that there was not a significant difference in MSR change scores between TG and CG.

Table 11

TG & CG: Independent Samples Effect Sizes MSR Differences

	Standardizer[a]	Point Estimate	95% Confidence Interval	
			Lower	Upper
Cohen's d	8.85	-.360	-1.092	.377
Hedges'g	9.106	-.350	-1.061	.367

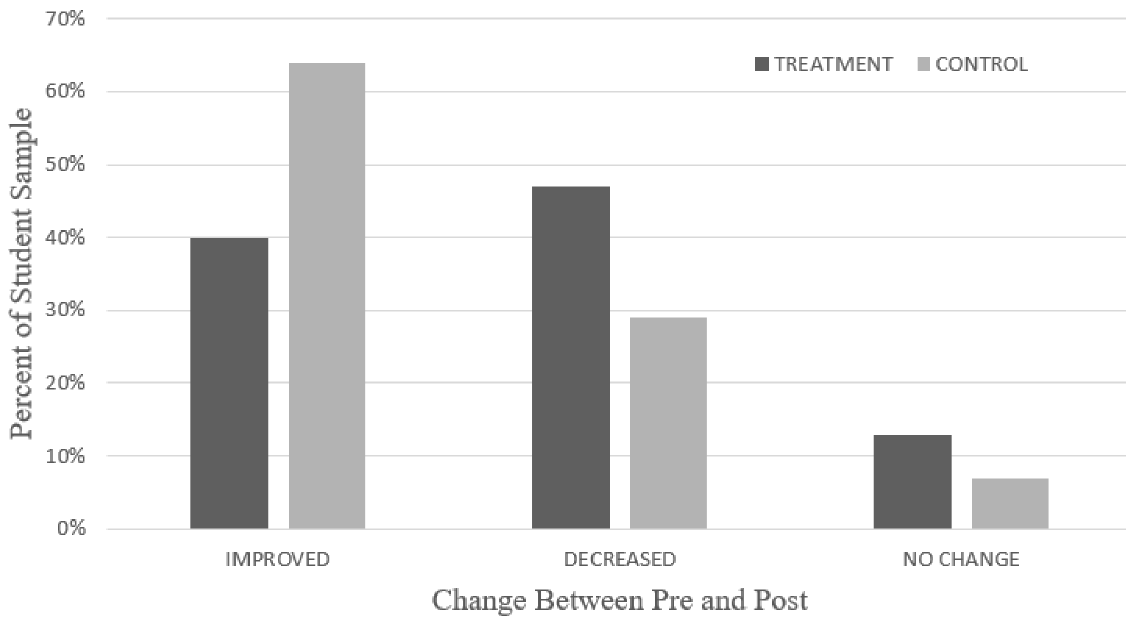
a. The denominator used in estimating the effect sizes

An analysis of Cohen's d and Hedges' g were used to measure the size of the difference (effect size) between pre and post differences for the TG and CG. Cohen's d used the sample deviation of the mean difference, which yielded a small effect size (d = -.360). Hedges' g continued to be used as part of a comparative analysis. The results of Hedges' g used the sample standard deviation of the mean difference, plus a correction factor and also found a small effect size (g = -.350).

Figure 2 illustrates the changes between the pre and post MSR values for TG and CG.

Figure 2

Changes Between Pre and Post MSR Values



RQ1: Is there a significant difference in *Self-Regulated Learning (SRL)* among the students who received the biofeedback intervention compared to those who did not?

H_O: There is no significant difference between *Self-Regulated Learning (SRL)* among the students who received the biofeedback intervention compared to those who did not.

H_1: There is a significant difference between *Self-Regulated Learning (SRL)* among the students who received the biofeedback intervention compared to those who did not.

As evident by the three administered *t*-tests, the results did not yield sufficient evidence to justify statical significance differences in SRL among students who received the biofeedback intervention compared to those who did not. The pretest/posttest design, which used the MSR instrument to measure SRL between the TG and CG, observed the most improved SRL in the CG. While there were pocketed areas of student growth across both groups, there were not strong enough findings to suggest that the biofeedback intervention made a statistically significant effect. Due to the non-significance of the independent sample *t*-test, the null hypothesis (H_o) for the RQ1 could not be rejected.

Research Question #2

RQ2: Is there a significant difference in *Time To Learn (TTL)* opportunities among the students who received the biofeedback intervention compared to those who did not?

Data were scored and computed using analysis methods in the Data Analysis Toolpack by Excel. The TG received 6 weeks of biofeedback intervention, while the students in the CG did not. Participants were treated the same in their respective groups. To answer RQ2, an independent samples *t*-test was conducted using a 2-tailed analysis to show the possibility of differences in both directions.

The dependent variable (TTL) was determined by the percentage of time students were together in the classroom receiving learning instruction (collected by the school's standard practice of a check-in/check-out system using hall passes). TTL was considered a continuous variable because percentages are measurable amounts of time. Average group TTL totals were calculated by collecting student TTL averages over the 6-week intervention period.

Table 12

TTL Averages: Group Statistics

	Mean	N	Std. Deviation	Std. Error Mean
Treatment	91%	15	.08003	.02066
Control	89%	15	.25016	.06459

The results showed that the TG had a higher TTL value of 91% than compared to the CG with 89%. These data suggested that the students from the TG spent more time together in the classroom than compared to the CG, which made them more available to receive learning instruction.

Table 13

TTL Averages: Independent Samples Test

	t-test for Equality of Means		Levene's Test for Equality of Variance		95% Confidence Interval of the Difference				Significance	
	Mean Difference	Std.Err Difference	F	Sig	Lower	Upper	t	df	One-Sided p	Two-Sided p
Equal Variances Assumed	.029	.068	1.217	.279	-.110	.168	.425	28	.337	.674
Equal Variances Not Assumed	.029	.068			-.114	.172	.425	16.8	.338	.676

To answer RQ2 using an independent samples *t*-test, a Levene's test was used to verify the equality of variances assumption. The assumption was supported by the non-significant finding from the Levene's test ($p = .279$). In other words, equal variances were assumed based on homogeneity of variance between the two groups. Moreover, the independent samples *t*-test was not statistically significant, $t(28) = 0.43$, $p = .674$, indicating that there was not a significant difference in TTL values between the TG and CG.

Table 14

TTL Averages: Independent Samples Effect Sizes

	Standardizer[a]	Point Estimate	95% Confidence Interval	
			Lower	Upper
Cohen's d	.1857	.155	-.563	.871
Hedges' g	.1908	.151	-.548	.847

a. The denominator used in estimating the effect sizes.

An analysis of Cohen's *d* and Hedges' *g* were used to measure the size of the difference (effect size) between the TTL differences for the TG and CG. Cohen's *d* used the sample deviation of the mean difference, which yielded a small effect size (d = .155). Hedges' *g* is commonly used for small sample sizes (<20) and was included as part of a comparative analysis. The results of Hedges' *g* used the sample standard deviation of the mean difference, plus a correction factor, and also found a small effect size (g = .151).

RQ2: Is there a significant difference in *Time To Learn (TTL)* opportunities among the students who received the biofeedback intervention compared to those who did not?

H_O: There is no significant difference between *Time To Learn (TTL)* opportunities among the students who received the biofeedback intervention compared to those who did not?

H_1: There is a significant difference between *Time To Learn (TTL)* opportunities among the students who received the biofeedback intervention compared to those who did not?

Despite the TTL value for the TG being 2% higher than the TTL value for the CG, the independent samples *t*-test did not find the group differences to be statistically significant, $t(28) = 0.43$, $p = .674$. This finding suggests that there was not a significant difference in TTL averages between the TG and CG. Due to the non-significance of the independent sample *t*-test, the null hypothesis (H_o) for RQ2 could not be rejected.

CHAPTER FIVE

Summary and Discussion

The purpose of this research was to investigate differences in Self-Regulated Learning (SRL) and Time To Learn (TTL) among students who received a biofeedback intervention compared to those who did not. The research comprised of a 6-week study of two similarly formed sophomore English classes (Treatment vs. Control) at a public secondary school in the northeast region of the United States. The study intended to further knowledge in the field of educational psychology by exploring the implementation of a biofeedback intervention as a Tiered 1 learning strategy for SRL and keep students in the classroom longer, making them more available for learning. All students in the study completed the Metacognitive Self-Regulated (MSR) subscale from the Motivated Strategies for Learning Questionnaire (MSLQ) before the 6-week intervention as a pretest and were administered the same test at the conclusion of the intervention as a posttest measure for SRL. The second dependent variable was TTL data, which were collected across the 30-student sample throughout the 6 weeks. All data analysis methods were scored and computed using the Data Analysis Toolpack by Excel.

This study's research findings are discussed and presented as follows: summative findings responding to each research question, conclusions of the study, and recommendations for future research.

Research Question #1

Is there a significant difference in *Self-Regulated Learning (SRL)* among the students who received the biofeedback intervention compared to those who did not?

Results from the pretest-posttest research design were carried out using three separate *t*-tests: a paired sample *t*-test (conducted to determine pre and post differences for the TG), a paired sample *t*-test (conducted to determine pre and post differences for CG), and an unpaired independent samples *t*-test (was developed to analyze the derived pre-post difference data between the TG and CG). The results from the paired two-tailed sample *t*-test for the CG were not statistically significant, $t(13) = -1.34$, $p = .204$, indicating that there was not a significant change in MSR scores between pretest and posttest among the student participants in the CG. Moreover, the results of the paired two-tailed sample *t*-test for the TG were also not statistically significant, $t(14) = -.40$, $p = .699$, indicating that there was not a significant change in MSR scores between pretest and posttest among participants in the TG. Additionally, the independent 2-tailed *t*-test also did not yield statistical significance, $t(27) = -0.97$, $p = .341$, indicating that there was not a significant difference in MSR change scores between TG and CG. Given the non-significance of the independent sample *t*-test, the null hypothesis (H_o) for the RQ1 could not be rejected.

Research Question #2

Is there a significant difference in *Time To Learn (TTL)* opportunities among the students who received the biofeedback intervention compared to those who did not?

An independent (unpaired) samples *t*-test was used to measure group TTL differences. The results suggested that there is not sufficient evidence to find the group differences to be statistically significant, $t(28) = 0.43$, $p = .674$. This finding indicated that there was not a significant difference in TTL averages between the TG and CG, and as a result of the non-significance of the independent sample *t*-test, the null hypothesis (H_o) for RQ2 could not be rejected.

Conclusions

The adolescent population was the most vulnerable to the pandemic's consequences because of their neurodevelopmental vulnerabilities (Calma-Birling & Zelazo, 2022; Drysdale, 2023; Jensen & Nutt, 2015; YRBS, 2021; Zadina, 2023). At a time of unprecedented change and developmental and emotional lability, adolescents faced life's uncertainty unprepared, operating under a premature brain and dysregulated body. They demonstrated skill deficits in the activation and sustainability of their cognitive processes toward attaining learning goals, otherwise referred to as Self-Regulated Learning (SRL) (Calma-Birling & Zelazo, 2022; Schunk & Zimmerman, 2008; Zadina, 2023). In secondary education, SRL opportunities are decreased or eliminated, while SRL demands and expectations on adolescent youth remain or are increased. This study set out to explore biofeedback (a psychophysiological technique) under the theoretical perspectives of operant conditioning, social cognitive theory, and self-regulated learning model as a potential SRL Tiered 1 strategy at the secondary level.

The inferential statistics revealed that students who used biofeedback for 6 weeks did not show a significant difference in SRL compared to those who did not. Similarly, the Time To Learn (TTL) opportunities did not provide sufficient evidence between the TG and CG to suggest a statistical difference. The study's univariate procedure involved measuring one dependent variable at a time using specifically designed *t*-tests. This statistical method was chosen to eliminate bias and determine if the results were due to chance or were clinically significant. The aim was to instill confidence in the results by deriving a critical value smaller than 0.05, indicating a less than 5% chance that the data were random, but a greater than 95% chance that the data were statistically significant. Despite the small effect sizes found across all statistical tests, the results, when considered together, indicated minimal effect sizes between the groups and did not demonstrate statistical significance. This suggests that there was insufficient evidence to generalize the results to the larger population, independent of the study's sample size.

Regardless of these outcomes, this study revealed some similar discoveries to that of other research, contributed valuable data to mitigate the identified problem facing the adolescent population, and added value to the field of educational psychology. First, this study supported previous research that charged that SRL cannot be measured in isolation. Biofeedback may have supported SRL but cannot be deemed as the only tool for students' improvements in SRL. For example, one student gained value in just having personal time before instructional time, "I like how we could have a few minutes on our own to relax." Furthermore, Boekaerts and Corno (2005) reviewed that there is no single instrument that can accurately assess SRL in isolation; instead, to properly measure SRL, one would need to use a combination of assessment instruments and methods. This study concurred, given that SRL improvements occurred across groups, regardless of biofeedback.

Next, this study's review of the literature and current research highlighted the vulnerabilities that confront adolescents today. During the COVID-19 pandemic, there were unknown implications related to adolescents' deficits in SRL and the critical importance for secondary schools to begin to consider. Following the study, a student reported a positive experience and a specific reminder of those vulnerable implications:

> My experience was pretty good, the biofeedback measured how I was doing and how I was connecting with myself. I think that understanding that there are influences outside or inside of a school that affect how people are feeling can also affect coherence levels, whether positive or negative.

What was known, was that the aftermath of COVID-19 brought about chronic school absences and avoidance (NEA, October 2023). Also known are the marked increases in neurobiological research on adolescent behaviors during adolescence. This study hopes that secondary schools will begin to teach SRL skills to their students and appreciate their students' vulnerabilities that may interfere with their learning potential.

Finally, it is the hope of this research study that educational practices consider exploring biofeedback as supplemental support for SRL in the classroom. Before this study, it was unknown if a biofeedback intervention could be used as an in-classroom SRL strategy at the secondary level. This study's intervention showed that the psychophysiological tool was widely accepted among the students, parents, administrators, and community stakeholders. Some students reported using this study's biofeedback strategy before taking a test, prior to performing in an orchestra concert, during volleyball practices, and before lacrosse games. A student showed support by saying:

> I enjoyed being in the study, and I feel like other people should do this too. I believe that other people should do this because it's a way to see how focused you can really get and an opportunity to learn if you can apply skills like this in the real world.

Moreover, the research reviewed on SRL and biofeedback overwhelmingly supported the theoretical frameworks used for this study while also showing the need for more information to determine statistical significance for larger populations. This empirical study addressed a wide range of scientific and educational literature that conveniently covered areas of shared concerns and interests. Despite two decades of brain-based learning research on bridging neuroscience with education, there have still been slow movements in the field to reinvent educational practice. It is valuable that the field of education sees the interconnected overlap in brain and body research, acknowledges the current problem with SRL, and approaches teaching adolescents differently in order to better prepare them with the resilience required to face the world beyond high school.

Recommendations for Future Research

The findings from this study suggest several directions for future research. The following recommendations should be considered and explored to further the knowledge elicited from this investigation:

The current study explored biofeedback as a Tier 1 intervention. Future research considerations should explore biofeedback as a targeted Tier 2 or Tier 3 intervention. The results from the current study showed SRL improvements in the CG, which was made up of 73% of students on educational plans (i.e., Individualized Education Plans or 504 accommodation plans). This evokes inquiry into whether students who receive educational modifications and accommodations may be better conditioned to receive benefits from biofeedback compared to students receiving general education.

The study promotes future research using a larger population with a similar design and method. The current study led to a plausible inquiry as to whether a larger sample size would have changed the results. Conversely, a similar research study using a shorter intervention period may be worth future consideration. The current design measured the biofeedback intervention across 6 weeks, which may have caused students to lose interest and make the activity lose its value (which is a critical component in the forethought phase of SRL). If value is lost, then students are less likely to achieve success (Zimmerman & Moylan, 2009).

The results from this study showed that the CG made more improvements in SRL; however, they had spent the least amount of time in the classroom, while the TG showed the least improvement in SRL and spent the most time together in the classroom. Future research is encouraged to explore the significance associated with TTL and the possibility that time out of the classroom may be considered an SRL strategy. Research supports that time in the classroom is important to learning; however, research has yet to explore how much time in and out of the classroom promotes SRL.

This topic merits an investigation into how SRL can potentially be promoted using a brief mind-body activity before learning instruction. This study explored biofeedback as a potential SRL strategy by having the students perform SRL behaviors and cognitive processes but did not directly teach SRL skills. This important difference can lead to interesting opportunities for future research. Future studies are suggested to measure SRL by employing a similar biofeedback intervention to adolescent youth while teaching them formal instruction on SRL skills.

More research on SRL during adolescence is encouraged. Bardach et al. (2023) announced that research on SRL is lacking in secondary education. Adolescent development is a critical period for SRL, and educational research can help influence student strengths during this time. Neuroscientists from the Alliance for Excellent Education have called for educators to foster a better school culture that supports adolescent development while addressing educational needs (Sparks, 2018). It is important for educators to have a basic understanding of adolescent psychophysiology so they know how to best approach teaching SRL skills to their students. Lastly, gender differences and cultural implications should be explored in similar studies of SRL and biofeedback. It would be relevant to gain a better understanding of subgroup differences to better support targeted interventions.

REFERENCES

Akhtar, J. & Mahmood, N. (2013). Development and validation of an academic self-regulation scale for university students. *Journal of Behavioural Sciences, 23*(2).

Alvarez, B. (2023, October). Teaching while scared. *National Education Association (NEA) Today*, 50-52.

American Academy of Pediatrics. (2013). Primary care tools. https://www.aap.org/en/patient-care/mental-health-initiatives/

Andrade, H. & Valtcheva, A. (2009). Promoting learning and achievement through self-assessment. *Theory Into Practice, 48*(1), 12-19.

Andreassi, J. (2000). *Psychophysiology: Human behavior & physiological response, 4th ed.* Taylor & Francis.

Aranberri-Ruiz, A., Aritzeta, A., Olarza, A., Soroa, G. & Mindeguia, R. (2022). Reducing anxiety and social stress in primary education: A breath-focused heart rate variability biofeedback intervention. *International Journal of Environmental Research and Public Health, 19,* 10181. https://doi.org/10.3390/ijerph191610181/

Arns, M., Heinrich, H., & Strehl., U. (2014). Evaluation of neurofeedback in ADHD: The long and winding road. *Biological Psychology, 95*, 108-115.

Artuch-Garde, R., Gonzalez-Torres, M., de la Fuente, J., Vera, M., Fernandez-Cabezas, M. & Lopez-Garcia, M. (2017). Relationship between resilience and self-regulation: a study of Spanish youth at risk of social exclusion. *Frontier Psychology, 8*. https://doi.org/10.3389/fpsyg.2017.00612/

Asato, M., Terwilliger, R., Woo, J. Luna, B. (2010). White matter development in adolescence: a DTI study. *Cerebral Cortex, 20,* 2122-2131. https://doi.org/10.1093/cercor/bhp282/

Azevedo, R., & Cromley, J. G. (2004). Does Training on Self-Regulated Learning Facilitate Students' Learning With Hypermedia? *Journal of Educational Psychology, 96(*3), 523–535. https://doi.org/10.1037/0022-0663.96.3.523/

Azevedo, R., Cromley, J. & Seibert, D. (2004). Does adaptive scaffolding facilitate students' ability to regulate their learning with hypermedia? *Contemporary Educational Psychology, 29*(3), 344-370.

Baars, M., Leopold, C. & Paas, F. (2018, May). Self-explaining steps in problem-solving tasks to improve self-regulation in secondary education. *Journal of Educational Psychology, 110*(4), 578-595). https://doi.org/10.1037/edu0000223

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory.* Prentice-Hall.

Bandura, A. (1991). Social cognitive theory of self-regulation. *Organizational Behavior and Human Decision Processes, 50*, 248-287.

Bandura, A. (2001). Social cognitive theory: An agentic perspective. *Annual Review of Psychology, 52*, 1-26.

Bannert, M., Hildebrand, M., & Mengelkamp, C. (2009). Effects of a metacognitive support device in learning environments. *Computers in Human Behavior*, *25*(4), 829–835. https://doi.org/10.1016/j.chb.2008.07.002/

Bardach, L., Yanagida, T., Goetz, T., Jach, H. & Pekrun, R. (2023). Self-regulated and externally regulated learning in adolescence: Developmental trajectories and relations with teacher behavior, parent behavior, and academic achievement. *Developmental Psychology, 59*(7), 1327-1345. https://doi.org/10.1037/dev0001537/

Bearden, A., Oostrom, S. & Brown, S. (2023). The effects of HeartMath heart lock-in on elementary students' HRV and self-reported emotional regulation skills. *Psychology in the Schools*, 1-19.

Beaumont, J., Putwain, D., Gallard, D., Malone, E. Marsh, H., & Pekrun, R. (2023). Students' emotional regulation and school-related well-being: longitudinal models juxtaposing between-and within-person perspectives. *Journal of Educational Psychology, 115*(7), 932-950. https://doi.org/10.1037/edu0000800/

Bembenutty, H. (2005). *Academic achievement in a national sample: the contribution of self-regulation and motivational beliefs beyond and above parental involvement.*

Berzonsky, M.D. (1988). *Self-theorists, identity status, and social cognition.* In: Lapsley, D.K., Power, F.C. (eds) Self, Ego, and Identity. Springer. https://doi.org/10.1007/978-1-4615-7834-5_12/

Best, J., Miller, P., Naglieri, J. (2011). Relations between executive function and academic achievement from ages 5 to 17 in a large, representative national sample. *Learning Individual Difference, 21*, 327-336. https://doi.org/10.1016/j.lindif.2011.01.007/

Bjorntorp, P. (1991) Visceral fat accumulation: the missing link between psychosocial factors and cardiovascular disease? *J Intern Med, 230*, 195–201.

Bloom, B. (1964). *Stability and change in human characteristics*. Wiley.

Boekaerts, M. (1999). Motivated learning: studying student situation transactional units. *European Journal of Psychology of Education, 14*(1), 41-55. https://doi.org./10.1007/bf03173110/

Boekaerts, M. & Cascallar, E. (2006). How far have we moved toward the integration of theory and practice in self-regulation? *Educational Psychology Review, 18*, 199-210. https://doi.org./10.1007/s10648-006-9013-4/

Boekaerts, M. & Corno, L. (2005). Self-regulation in the classroom: A perspective on assessment and intervention. *Applied Psychology: An International Review, 54*(2), 199-231.

Borg, W. (1980). *Time and school learning.* In C. Denham & A. Lieberman (Eds.), *Time to learn.* National Institute of Education.

Bothe, D., Grignon, J. & Olness, K (2014). The effects of a stress management intervention in elementary school children. *Journal of Developmental & Behavioral Pediatric, 35*(1), 62-67. https://doi.org/10.1097/dbp.0000000000000016/

Bozpolat, E. (2016). Investigation of the self-regulated learning strategies of students from the faculty of education using ordinal logistic regression analysis. *Educational Sciences: Theory & Practice, 16*, 301-318.

Bradley, R., McCraty, R., Atkinson, M., Arguelles, L., Rees, R., Tomasino, D. (2007). *Reducing test anxiety and improving test performance in America's schools.* Institute of Heart-Math.

Bradley, R., McCraty, R., Atkinson, M., Tomasino, D., Daugherty, A., & Arguelles, L. (2010). Emotion self-regulation, psychophysiological coherence and test anxiety: Results from an experiment using electrophysiological measures. *Applied Psychophysiology and Biofeedback, 35,* 261-283. https://doi.org/10.1007/s10484-010-9134-x/

Broadbent, J., & Poon, W. (2015). Self-regulated learning strategies & academic achievement in online higher education learning environments: A systematic review. *The Internet and Higher Education, 27*, 1-13.

Brown, B., & Saks, D. (1986). Measuring the effects of instructional time on student learning: Evidence from the beginning teacher evaluation study. *American Journal of Education, 94*, 480-500.

Brozovich, M., Kurland, E. & McGoey, K. (2021). *Executive functions in early childhood* [Research Summary]. National Association of School Psychologists.

Brunner, E. et al. (2002) Adrenocortical, autonomic, and inflammatory causes of the metabolic syndrome: nested case-control study. *Circulation, 106*, 2659–2665.

Butler, D., Cartier, S., Schneider, L., Gagnon, F. & Giammarino, M. (1995). Secondary students' self-regulated engagement in reading: researching self-regulation as situated in context. *Psychological Test and Assessment Modeling, 53*(1), 161-179.

Cai, R., Wang, Q., Xu, J., Zhou, L. (2020). Effectiveness of students' self-regulated learning during the COVID-19 pandemic. *Science Insights, 34*(1):175-182.

Calma-Birling, D. & Zelazo, P. (2022). A network analysis of high school and college students' COVID-19-related concerns, self-regulatory skills, and affect. *American Psychologist, 77*(6), 727-742.

Carlo, G., Crockett, L., Wolff, J., & Beal, S. (2012). The role of emotional reactivity, self-regulation and puberty in adolescents' prosocial behaviors. *Social Development, 21*, 667-685. https://doi.org/10.1111/j.1467-9507.2912.00660.x/

Carmody, D., Radvanski, D., Wadhwani, S., Sabo, M., & Vergara, L. (2000). EEG biofeedback training and attention-deficit/hyperactivity disorder in an elementary school setting, *Journal of Neurotherapy: Investigations in Neuromodulation, Neurofeedback and Applied Neuroscience, 4*(3), 5-27, htTTL://dx.doi.org/10.1300/J184v04n03_02/

Casey, B., & Caudle, K. (2013). The teenage brain: Self-control. *Current Directions in Psychological Science, 22*(2), 82-87. https://doi.org/10.1177/0963721413480170/

Casey, B., Heller, A., Gee, D., Cohen, A. (2019). Development of the emotional brain. Neuroscience Letters. 693, 29-34. https://doi.org/10.1016/j.neulet.2017.11.055/

Cell Press (2019). A lack of self-control during adolescence is not uniquely human. *ScienceDaily, 20*.

Chandola, T., Brunner, E., Marmot, M. (2006) Chronic stress at work and the metabolic syndrome: prospective study. *BMJ 332,* 521–525.

Chi, M., Bassok, M., Lewis, M., Reimann, P. & Glaser, R. (1989). Self-explanations: How students study and use examples in learning to solve problems. *Cognitive Science, 13*, 145-182.

Chin, J., Di Maio, J., Weeraratne, T., Kennedy, K., Oliver, L., Bouchard, M., Malhotra, D., Habashy, J., Ding, J., Bhopa, S., Strommer, S., Hardy-Johnson, P. Barker, M., Sloboda, D., & McKerracher, L. (2023). Resilience in adolescence during the COVID-19 crisis in Canada. *BMC Public Health, 23,* 1097. https://doi.org/10.1186/s12889-023-15813-6/

Cho, Y., & Jonassen, D. (2012). Learning by self-explaining causal diagrams in high school biology. *Asia Pacific Education Review, 13,* 171-184.

Christodoulou, G., & Black, D. (2020). The utility of heart variability in mindfulness research. *Mindfulness, 11*(3), 554-570. https://doi.org/10.1007/s12671-019-01296-3/

Chu, L. Li, P. & Yu, M. (2020). The longitudinal effect of children's self-regulated learning on reading habits and well-being. *International Journal of Education Research, 104*, https://doi.org/10.1016/j.ijer.2020.101673

Cook, K. B., & Sayeski, K. L. (2022). High-school students with high-incidence disabilities' use of smarTTLhones for self-monitoring. *Exceptionality, 30*(4), 279–295. https://doi.org/10.1080/09362835.2020.1772064/

Corno, L. (1993). The best laid plans: Modern conception of volition and educational research. *Educational Researcher, 22*,14-22.

Corno, L., Cronbach, L., Kupermintz, H., Lohman, D., Mandinach, E., Porteus, A. & Talbert, J. (2002). *The Stanford aptitude seminar. Remarking the concept of aptitude: Extending the legacy of Riachard E. Snow.* Erlbaum.

Cotton, K., & Savard, W. (1981). *Time factors in learning.* Northwest Regional Educational Laboratory.

Creswell, J. (2014). *Research design: Qualitative, quantitative and mixed methods approaches, fourth edition*. Sage.

De Bruin, A., & Van Gog, T. (2012). Improving self-monitoring and self-regulation: From cognitive psychology to the classroom. *Learning and Instruction, 22*(4), 245–252. https://doi.org/10.1016/j.learninstruc.2012.01.003/

De Leeuw, M., Bohlken, M., Mandl, R., Hillegers, M., Kahn, R. & Vink, M. (2017). Changes in white matter organization in adolescent offspring of schizophrenic patients. *Neuropsychopharmacology, 42*, 496-501. https://doi.org/10.1038/npp.2016.130/

Demos, J. (2019). *Getting started with EEG neurofeedback, second edition.* W. W. Norton & Company.

Dent, A. L., & Koenka, A. C. (2016). The relation between self-regulated learning and academic achievement across childhood and adolescence: *A meta-analysis. Educational Psychology Review, 28*(3), 425–474. https://doi.org/10.1007/s10648-015-9320-8/

Diamond, A. (2013). Executive functions. *Annual Review of Psychology, 64*, 135-168.

DiCara, L., & Miller, N. (1968). Instrumental learning of vasomotor responses by rats: Learning to respond differentially in the two ears. *Science, 159,* 1485-1486.

Dignath, C. & Büttner, G. (2008). Components of fostering self-regulated learning among students. A meta-analysis on intervention studies at primary and secondary school level. *Metacognition Learning 3*, 231–264. https://doi.org/10.1007/s11409-008-9029-x/

Dong, L. (2023). Examining the relationship between socioeconomic status, self-regulated learning strategies, and writing proficiency in English as a second language learning context. *Journal of Educational Psychology,* Advance online publication. https://dx.doi.org/10.1037/edu0000834/

Drysdale, S. (2023, October 24th). *Public school chronic absenteeism has spiked since 2019*. Mass Nonprofit News. https://www.massnonprofit.org/news/public-school-chronic-absenteeism-has-spiked-since-2019/article_ce470802-72c3-11ee-b28d-b7f6dcc771fc.html?utm_source=massnonprofit.org&utm_campaign=%2Fnewsletter%2Foptimize%2Fweekly-headlines%2F%3F-dc%3D1698231602&utm_medium=email&utm_content=read%20more/

DuBois, D. Felner, R., Brand, S., Adan, A. & Evans, E. (1992). A prospective study of life stress, social support, and adaptation in early adolescence. *Child Development, 63*(3), 542-557. https://doi.org/10.2307/1131345/ as referenced in Lessard, L. & Puhl, R. (2021). Adolescent academic worries amid Covid-19 and perspectives on pandemic-related changes in teacher and peer relations. *School Psychology, 36*(5) 285-292. https://doi.org/10.1037/spq0000443/

Dweck, C. (2008). *Mindset: The new psychology of success, How we can learn to fulfill our potential.* Ballantine Books.

Dynarski, M., James-Burdumy, S., Moore, M., Rosenberg, L., Deke, J., & Mansfield, W. (2004). *When schools stay open late: The national evaluation of the 21st century community learning centers program: New findings.* U.S. Department of Education / Institute of Education Sciences.

Ellis, W., Dumas, T. & Forbes, L. (2020). Physically isolated but socially connected: Psychological adjustment and stress among adolescents during the initial COVID-19 crisis. *Canadian Journal of Behavioural Science, 52*(3), 177-187. https://doi.org/10.1037/cbs0000215/

Erikson, E. (1968). *Identify, youth and crisis.* Norton & Company.

Farbman, D. (2015). The case for improving and expanding time in school: A review of key research and practice. *National Center on Time & Learning*.

Frank, C. (2023, March 10th). *HeartMath in education: Building resilience, social-emotional competencies, and cognitive skills.* https://christianafrank.com/

Frazier, J., & Morrison, F. (1998). The influence of extended-year schooling a growth of achievement and perceived competence in early elementary school. *Child Development, 69*(2), 495-517.

Fuller, G. (1984). *Biofeedback: Methods and procedures in clinical practice.* Biofeedback Press. In Thompson, M. & Thompson, L. (2015). *The neurofeedback book, second edition.* The Association for Applied Psychophysiology and Biofeedback.

Gardner, D., et al. (1983). *A nation at risk: The imperative for educational reform. An open letter to the American people. A report to the nation and secretary of education.* National Commission on Excellence in Education.

Gettinger, M & White, M. (1979). Which is the stronger correlate of school learning? Time to learn or measured intelligence? *Journal of Educational Psychology, 71*(4), 405-412.

Gordon, E., Chauvin, R., Van, A.. et al. (2023). A somato-cognitive action network alternates with effector regions in motor cortex. *Nature 617,* 351–359. https://doi.org/10.1038/s41586-023-05964-2/

Graham, S. & Harris, K. (2000). The role of self-regulation and transcription skills in writing and writing development, *Educational Psychologist, 35*(1), 3-12. https://doi.org/10.1207/S15326985EP3501_2/

Graham, S., & MacArthur, C. (1988). Improving learning disabled students' skills at revising essays produced on a word processor: Self-instructional strategy training. *The Journal of Special Education, 22*(2), 133-152. https://doi.org/10.1177/002246698802200202/

Green, E., Green, A. & Walters, E. (1979). Biofeedback for mind/body self-regulation: Healing and creativity. In: Peper, E., Ancoli, S. & Quinn, M. (Eds). Mind/body integration. Springer. https://doi.org/10.1007/978-1-4613-2898-8_9

Griffin, T., Wiley, J. & Thiede, K. (2008). Individual differences, rereading, and self-explanation: Concurrent processing and cue validity as constraints on metacomprehension accuracy. *Memory & Cognition, 36,* 93-103. htTTL://dx.doi.org/10.3758/MC.36.1.93/

Gupta, M. & Mehtani, D. (2017). Construction and validation of self-regulated learning scale (SRLS): An exclusive mechanism for promoting learning performance. *Journal of Educational Psychology Research, 7*(1), 84-95.

Hall G. (1904). *Adolescence: In psychology and its relation to physiology, anthropology, sex, crime, religion, and education* (1). Prentice-Hall.

HeartMath Institute. (2018). Welcome to inner balance. https://cdn.heartmath.com/meanuals/inner_balance_ios_android.pdf/

HeartMath Institute. (2020). Inner Balance coherence sensor. https://www.heartmath.org/store/products/inner-balance/

HeartMath Institute Science. (2024). Scientific foundation of the HeartMath system. https://www.heartmath.org/science/

Hibbs, S. (2007). *Anxiety gone: The three c's of anxiety recovery.* Dare2Dream Books.

Hoxby, C. & Murarka, S. (2008). New York City charter schools: How well are they teaching their students? *Education Next*, 54-61.

Hunt, J. (1961). *Intelligence and experience*. Ronald Press.

Ilker, G. (2014). Effects of feedback on achievement goals and perceived motivational climate in physical education. *Issues in Educational Research, 24*(2), 152-161.

Jansen, R., van Leeuwen, A., Janssen, J. & Jak, S. (2019). Self-regulated learning partially mediates the effect of self-regulated learning interventions on achievement in higher education: a meta-analysis. *Educational Research Review, 28*, 100292. https://doi.org/10.1016/j.edurev.2019.100292/

Jarrett, O., Maxwell, D., Dickerson, C., Hoge, P., Davies, G. & Yetley, A. (1998). The impact of recess on classroom behavior: Group effects and individual differences. *Journal of Educational Research, 92*(2), 121-126.

Jensen & Nutt (2015). *The Teenage Brain*: *A neuroscientist's survival guide to raising adolescents and young adults.* Harper.

Jindal-Snape, D., Hannah, E., Cantali, D., Barlow, W., & MacGillivray, R. (2020). Systematic literature review of primary-secondary transitions: International Research. *Review of Education, 8*(2), 526-566. Https://doi.org/10.1002/rev3.3197/

Jonsson, A. (2013). *Communicating expectations through the use of rubrics.* Paper presented at the EARLI Conference 2013, Munich, Germany

Karavaev, A., Kiselev, A., Gridnev, V., Borovkova, E., Prokhorov, M., Posnenkova, O. & Shvarts, V. (2013). Phase and frequency locking of 0.1-Hz oscillations in heart rate and baroreflex control of blood pressure by breathing of linearly varying frequency as determined in healthy subjects. *Human Physiology, 39*, 416-425.

Kimmel, H. (1967). Instrumental conditioning of autonomically mediated behavior. *Psychological Bulletin, 67*, 337-345.

Kirwan, J., Lounsbury, J. & Gibson, L. (2014). An investigation of the big five and narrow personality traits in relation to self-regulated learning. *Journal of Psychology and Behavioral Science, 2*(1), 1-11.

Kosnin, A. (2007). Self-regulated learning and academic achievement in Malaysian undergraduates. *International Educational Journal, 8*(1), 221-228.

Kostons, D., Van Gog, T., & Paas, F. (2012). Training self-assessment and task-selection skills: A cognitive approach to improving self-regulated learning. *Learning and Instruction, 22*, 121–132. https://doi.org/10.1016/j.learninstruc.2011.08.004/

Ladouceur, C. D., Peper, J. S., Crone, E. A., & Dahl, R. E. (2012). White matter development in adolescence: the influence of puberty and implications for affective disorders. *Developmental cognitive neuroscience*, *2*(1), 36–54. https://doi.org/10.1016/j.dcn.2011.06.002/

Lapides, J., Sweet, R. & Lewis, L. (1957). Role of striated muscle in urination. *Journal of Urology, 77,* 247-253.

Lauer, P., Akiba, M., Wilkerson, S., Apthorp, H., Snow, D., & Martin-Glenn, M. (2006). Out-of-school-time programs: A meta-analysis of effects for at-risk students. *Review of Educational Research, 76*(2), 275-313.

Lessard, L. & Puhl, R. (2021). Adolescent academic worries amid covid-19 and perspectives on pandemic-related changes in teacher and peer relations. *School Psychology, 36*(5) 285-292. https://doi.org/10.1037/spq0000443/

Light, I. & Bincy, R. (2016). Effect of stress management interventions on job stress among nurses working in critical care units. *Texila International Journal of Nursing, 2*(1).

Lin, I., Wang, S., Fan, S., Peper, E. & Huang, C. (2020). A single session of heart rate variability biofeedback produced greater increases in heart rate variability than autogenic training. *Applied Psychophysiology Biofeedback, 45*, 343-350.

Massachusetts Department of Elementary and Secondary Education (2023). Chronic absence and student attendance. https://www.doe.mass.edu/sfs/attendance/#:~:text=Massachusetts%20defines%20chronically%20absent%20as,the%20reason%20for%20the%20absence/

Mastrotheodoros, S., Graaff, J., Dekovic, M., Meeus, W., & Branje, S. (2019). Coming closer in adolescence: Convergence in mother, father, and adolescent reports of parenting. *Journal of Research on Adolescence, 29*(4), 846-862. https://doi.org/10.1111/jora.12417/

May, R., Seibert, G., Sanchez-Gonzalez, M. & Fincham, F. (2018). Self-regulatory biofeedback training: an intervention to reduce school burnout and improve cardiac functioning in college students. *Stress*, https://doi.org/10.1080/10253890.2018.1501021/

McClelland, M., Geldhof, J., Morrison, F., Gestsdottie, S., Cameron, C., Bowers, E., Duckworth, A., Little, T., & Grammer, J. (2018). Self-regulation. In Halfon, N., Forrest, B., Lerner, M., & Faustman, M. (Eds.), *Handbook of life course health development* (275-298), Springer. https://doi.org/10.1007/978-3-319-47143-3_12

McCraty, R. (2005). Enhancing emotional, social, and academic learning with heart rhythm coherence feedback. *Biofeedback, 33*.

McCraty, R., Moor, S., Goelitz, J., & Lance, S. (2016). *Transforming stress for teens: The HeartMath solution for staying cool under pressure.* Instant Help Books, New Harbinger Publications, Inc.

McCraty, R., Tomasino, D., Atkinson, M., Aasen, P. & Thurik, S. (2000). Improving test-taking skills and academic performance in high school students using heartmath learning enhancement tools. *Institute of HeartMath*.

McCraty, R., & Zayas, M. (2014). Cardiac coherence, self-regulation, autonomic stability, and psychosocial wellbeing. *Frontiers in Psychology, 5.*

McKeachie, W. (1986). Teaching psychology: Research and experience. In V. P. Makosky (Ed.), *The G. Stanley Hall Lecture Series, 6*, 169–191. American Psychological Association. https://doi.org/10.1037/10310-005

McLeod, C. & Boyes, M. (2021). The effectiveness of social-emotional learning strategies and mindful breathing with biofeedback on the reduction of adolescent test anxiety. *Canadian Journal of Education, 44*(3), 815-847.

Mihalca, L., & Mengelkamp, C. (2020). Effects of induced levels of prior knowledge on monitoring accuracy and performance when learning from self-regulated problem solving. *Journal of Educational Psychology, 112*(4), 795–810. https://doi.org/10.1037/edu0000389/

Miller, R., Moran, M., Shomaker, L., Seiter, N., Sanchez, N., Verros, M., Rayburn, S., Johnson, S., & Lucas-Thompson, R. (2021). Health effects of COVID-19 for vulnerable adolescents in a randomized control trial. *School Psychology, 36*(5), 293-301.

Mischel, W., Shoda, Y., & Rodriguez, M. (1989). Delay of gratification in children. *Science, 244* (4907), 933-938.

Moffitt, T. E., Arseneault, L., Belsky, D., Dickson, N., Hancox, R. J., Harrington, H., Houts, R., Poulton, R., Roberts, B. W., Ross, S., Sears, M. R., Thomson, W. M., & Caspi, A. (2011). A gradient of childhood self-control predicts health, wealth, and public safety. *Proceedings of the National Academy of Sciences of the United States of America*, *108*(7), 2693–2698. https://doi.org/10.1073/pnas.1010076108

Murray, D. & Rosanbalm, K. (2017). *Promoting self-regulation in adolescents and young adults: A practice brief.* OPRE Report #2015-82. Washington, DC: Office of Planning, Research, and Evaluation, Administration for Children and Families, U.S. Department of Health and Human Services.

NASA (2023, January 23rd). *Experiments to unlock how human bodies react to long space journeys*, NASA Human Research Program Strategic Communications. https://www.nasa.gov/feature/experiments-to-unlock-how-human-bodies-react-to-long-space-journeys/

National Education Association (NEA) (2023). October Issue.

National Public Radio (NPR). (2023, October 10th). All things considered. https://www.npr.org/2023/10/10/1204800597/study-finds-the-school-absenteeism-rate-is-double-what-it-was-before-covid/

Nelson, T., Narens, L. (1990). Metamemory: A theoretical framework and some new findings. Found in Bower, G. (Ed). *The psychology of learning and motivation*, Academic Press, 26, 125-173.

Nietfeld, J. L., Cao, L., & Osborne, J. W. (2006). The effect of distributed monitoring exercises and feedback on performance, monitoring accuracy, and self-efficacy. *Metacognition and Learning, 1,* 159-179.

Nocentini, A., Palladino, B., & Menesini, E. (2021). Adolescents' stress reactions in response to COVID-19 pandemic at the peak of the outbreak in Italy. *Clinical Psychological Science, 9*(3), 507-514. https://doi.org/10.1177/2167702621995761/

Opdenakker, M. (2002). Developments in early adolescents'' self-regulation: The importance of teachers' supportive vs. undermining behavior. *Frontiers in Psychology, 13*. https://doi.org/10.3389/fpsyg.2022.1021904/

Ormond, J. (2020). *Human learning, 8th ed.* Pearson.

Panadero, E. (2017). A review of self-regulated learning: six models and fours directions for research. *Frontier Psychology, 8,* 422. https://doi.org/10.3389/fpsyg.2017.00422

Panadero, E., & Alonso-Tapia, J. (2014). How do students self-regulate? Review of Zimmerman's cyclical model of self-regulated learning. *Anales De Psycologia (English translated version), 30*(2), 450-462. htTTL://dx.doi.org/10.6018/analesps.30.2.167221

Panadero, E. & Jonsson, A. (2013). The use of scoring rubrics for formative assessment purposes revisited: A review. *Educational Research Review, 9*(0), 129-144. https://doi.org/10.1016/j.edurev.2013.01.002

Pas, P., Hulshoff Pol, H., Raemaekers, M, & Vink, M. (2021). Self-regulation in the pre-adolescent brain. *Developmental Cognitive Neuroscience, 51*.

nfield, W. & Boldrey, E. (1937). Somatic motor and sensory representation in the cerebral cortex of man studied by electrical stimulation. *Brain, 60,* 389-443.

Peper, E. & Shaffer, F. (2018). Biofeedback history: An alternative view. *Biofeedback, 38*(4), 142-147.

Perry, N., Phillips, L. & Hutchinson, L. (2006). Preparing student teachers to support for self-regulated learning. *Elementary School Journal, 106*, 237-254.

Pintrich, P. (1991). *A manual for the use of the Motivated Strategies for Learning Questionnaire (MSLQ).*

Pintrich, P. (2000). "The role of goal orientation in self-regulated learning" in *Handbook of Self-Regulation*, (eds.) Boekaerts, M., Pintrich, P. & Zeidner, M. Academic Press, 452-502.

Pintrich, P. (2002). Multiple goals, multiple pathways: The role of goal orientation in learning and achievement. *Journal of Educational Psychology, 9*, 544-555.

Pintrich, P., Smith, D., Garcia, T., & McKeachie, W. (1993). Reliability and predictive validity of the Motivated Strategies for Learning Questionnaire (MSLQ). *Educational and Psychological Measurement, 53*(3), 801-813.

Pintrich, P. R. (1988a). A process-oriented view of student motivation and cognition. In J. Stark & L. Mets (Eds.), *Improving teaching and learning through research: New directions for institutional research* (Vol. 57, pp. 65-79). Jossey-Bass.

Pintrich, P. R. (1988b). Student learning and college teaching. In R. E. Young & K. E. Eble (Eds.), *College teaching and learning: Preparing for new commitments. New directions for teaching and learning* (Vol. 33, pp. 71-86). Jossey-Bass.

Pintrich, P. R. (1989). The dynamic interplay of student motivation and cognition in the college classroom. In C. Ames & M. Maehr (Eds.), *Advances in motivation and achievement: Motivation-enhancing environments* (Vol. 6, pp. 117-160). JAI Press.

Pintrich, P. R., & DeGroot, E. (1990). Motivational and self-regulated learning components of classroom academic performance. *Journal of Educational Psychology, 82*, 33-40.

Pintrich, P. R., & Garcia, T. (1991, in press). Student goal orientation and self-regulation in the college classroom. In M. Maehr & P. R. Pintrich (Eds.), *Advances in motivation and achievement: Goals and self-regulatory processes,* (Vol. 7). JAI Press.

Porges, S. (2022). Polyvagal theory: A science of safety. Frontier of Integrated *Neuroscience*, 16.

PracticeWise Evidence-Based Services (PWEBS) Database (2023). *The blue menu of evidence-based psychosocial interventions for youth.* https://www.practicewise.com/Community/BlueMenu/

Radovan, M. (2011). The relation between distance students' motivation, their use of learning strategies, and academic success. *The Turkish Online Journal of Educational Technology, 10*(1), 217-222.

Ragelienė, T. (2016). Links of Adolescents Identity Development and Relationship with Peers: A Systematic Literature Review. *Journal of the Canadian Academy of Child and Adolescent Psychiatry*, *25*(2), 97-105. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4879949/

Raihan, A. (2011). Think-aloud techniques used in metacognition to enhance self-regulated learning. *Journal of Educational Research, 25*(2), 125-160.

Riley, J. (2023, September). Educational vision and catalog of aligned supports. *Department of Elementary and Secondary Education (DESE).* https://www.doe.mass.edu/commissioner/vision/vision-supports.pdf/

Ripolles, P., Marco-Pallares, J., Hielscher, U., Mestre-Misse, A., Templelmann, C., Heinze, H., Rodriquez-Fornells, A. & Noesselt, T. (2014). The role of reward in word learning and its implications for language acquisition. *Current Biology, 24,* 2606-2611.

Romeo, R. (2013). *The teenage brain: The stress response and the adolescent brain, 22(2*):140-145. https://doi.org/10.1177/0963721413475445/

Roth, A., Ogrin, S., & Schmitz, B. (2016). Assessing self-regulated learning in higher education: A systematic literature review of self-report instruments. *Educational Assessment, Evaluation and Accountability, 28,* 225-250.

Rotto, K. (2022, September). Communication matters: National school psychology week: Together we shine. *Communique, 51*(1) 26-31.

Russo, G., Oliveri, S., Cincidda, Guiddi, P. & Pravettoni, G. (2020). Exploring public attitude toward biofeedback technologies: Knowledge, preference and personality tendencies. *Journal of Public Health Research, 9* (1782).

Santrock, J. (2006). *Educational psychology.* Boston: McGraw Hills.

Sapolsky, R. (2018). *Behave: The biology of humans at our best and worst.* Penguin Books.

Sarwari, A. & Wahab, M. (2018). The effectiveness of the quick coherence technique using heart rate variability-biofeedback technology on the recovery of heart coherence among university students. *Pertanika Journal of Science and Technology, 26*(3).

Sattar, F. A., & Valdiya, P. S. (1999). Biofeedback in medical practice. *Medical journal, Armed Forces India*, *55*(1), 51–54. htTTLs://doi.org/10.1016/S0377-1237(17)30315-5/

Sauer, S. Burris, J., & Carlson, C. (2010). New directions in the management of chronic pain: self-regulation theory as a model for integrative clinical psychology practice. *Clinically Psychology Review, 30*, 805-814.

Schell, A., & Dawson, M. (2001). *Psychophysiology.* International Encyclopedia of the Social & Behavioral Sciences.

Schneider, W. (2008). The development of metacognitive knowledge in children and adolescents: Major trends and implication for education. *Mind, Brain, and Education, 2,* 114-121.

Schuitema, J., Peetsma, T. & van der Veen, I. (2012). Self-regulated learning and students' perceptions of innovative and traditional learning environments: a longitudinal study in secondary education. *Educational Studies, 38*, 397-413. https://doi.org/10.1080/03055698.2011.643105/

Schunk, D. & Ertmer, P. (2000). *Self-regulation and academic learning: self-efficacy enhancing interventions.* In Boekaerts, M., Pintrich, P., & Zeidner, M. (Eds.). *Handbook of self-regulation*. Academic Press.

Schunk, D. & Zimmerman, B. (1994). *Self-regulation of learning and performance: Issues and educational applications.* Lawrence Erlbaum Associates.

Schunk, D. & Zimmerman, B. (2008). *Motivation and self-regulated learning: Theory, research, and applications.* Taylor & Francis Group.

Scott, S., Rivera, K., Rushing, E., Manczak, E. Rozek, C., & Doom, J. (2021). "I Hate This": A qualitative analysis of adolescents' self-reported challenges during the COVID-19 pandemic. *Journal of Adolescent Health, 68*(2), 262-269. https://doi.org/10.1016/j.jadohealth.2020.11.010/

Shoemaker, K., Mulder, H., Deković, M., & Matthys, W. (2013). Executive functions in preschool children with externalizing behavior problems: a meta-analysis. *Journal of abnormal child psychology*, *41*(3), 457–471. https://doi.org/10.1007/s10802-012-9684-x/

Schuitema, J., Peetsma, T. & van der Veen, I. (2012). Self-regulated learning and students' perceptions of innovative and traditional learning environments: a longitudinal study in secondary education. *Educational Studies, 38*(4), 397-413.

Sha'ari, N., & Amin, M. (2021). *IOP Conference Series: Materials Science and Engineering, 1051* (012015). https://doi.org/10.1088/1757-899X/1051/1/012015/

Shen, H., Gong, Q., Aoki, C., Yuan, M., Ruderman, Y., Dattilo, M., William, K., & Smith, S. (2007). Reversal of neurosteroid effects at $\alpha4\beta2\delta$ $GABA_A$ receptors triggers anxiety at puberty. *Nature Neuroscience 10*, 469–477. https://doi.org/10.1038/nn1868/

Skinner, B. F. (1937). Two types of conditioned reflex: A reply to Konorski and Miller. *The Journal of General Psychology, 16*(1).

Somerville L., & Casey B. (2010). Developmental neurobiology of cognitive control and motivational systems. *Current Opinion in Neurobiology*, 20, 236–241.

Somerville, L., Hare, T., Casey, B. (2011). Front striatal maturation predicts cognitive control failure to appetitive cues in adolescents. *Journal of Cognitive Neuroscience, 23*(9), 2123-2134. https://doi.org/10.1162/jocn.2010.21572/

Somerville, L., Jones, R., & Casey, B. (2010). A time of change: Behavioral and neural correlates of adolescent sensitivity to appetitive and aversive environmental cues. *Brain and Cognition*, *72*(1), 124–133. https://doi.org/10.1016/j.bandc.2009.07.003/

Sparks, S. (2018, October 9th). *The teen brain: How schools can help students manage emotions and make better decisions.* Education Week.

Staddon, J. & Cerutti, D. (2003). Operant conditioning. *Annual Review of Psychology,* 54.

Stark, R., & Krause, U. (2009). Effects of reflection prompts on learning outcomes and learning behaviour in statistics education. *Learning Environments Research, 12*, 209-223.

Steffens, K. (2006). Self-regulated learning in technology-enhanced learning environments: lessons of a European peer reviews. *European Journal of Education, 41*(3-4).

Sterman, M., Wyrwicka, W., Roth, S. (1969). Electrophysiological correlates and neural substrates of alimentary behaviors in the cat. *Ann. N.Y. Acad. Sci.* 157, 723-739.

Striefel, S. (2001). Ethical Research Issues: Going beyond the declaration of Helsinki. *Applied Psychophysical Biofeedback 26*, 39–59. https://doi.org/10.1023/A:1009515621157/

Theobald, M. (2021). Self-regulated learning training programs enhance university students' academic performance, self-regulated learning strategies, and motivation: meta-analysis. *Contemporary Educational Psychology, 661*(1), 101976. https://doi.org/10.1016/j.cedpsych.2021.101976/

Thiede, K., Anderson, M., & Therriault, D. (2002). Accuracy of metacognitive monitoring affects learning of texts. *Journal of Educational Psychology, 95*, 66-73. htTTL://dx.doi.org/10.1037/0022-0663.95.1.66/

Thompson, M., & Thompson, L. (2015). *The neurofeedback book, second edition. An introduction to basic concepts in applied psychophysiology.* The Association for Applied Psychophysiology and Biofeedback.

Tyborowska, A., van den Berg, Y., Hashemi, M., Niermann, H., Cillessen, A., Toni, I., & Roelofs. (2023). Neural patterns of threat response in adolescents predict vulnerability for and resilience against internalizing symptoms during COVID-19 waves. *Neuroimage Reports,* 100177.

Utley, A., & Garza, Y. (2011). The therapeutic use of journaling with adolescents. *Journal of Creativity in Mental Health, 6*(1), 29-41. htTTL://www.doi/10.1080/15401383.2011.557312/ as referenced in Rotto, K. (2022, September). Communication matters: National school psychology week: Together we shine. *Communique, 51*(1) 26-31.

Van der Veen, I., & Peetsma, T. (2009). The development in self-regulated learning behaviors of first-year students in the lowest level of secondary school in the Netherlands. *Learning and Individual Differences, 19*, 34-46, https://doi.org/10.1016/j.lindif.2008.03.001/

Van Loon, M., & Oeri, N. (2023). Examining on-task regulation in school children: Interrelations between monitoring, regulation, and task performance. *Journal of Educational Psychology, 115*(3), 446-459.

Venitz, L., & Perels, F. (2018). Promoting self-regulated learning of preschoolers through indirect intervention: a two-level approach, *Early Childhood Development Care, 189*, 2057-2070. https://doi.org/10.1080/03004430.2018.1434518/

Vink, M., Gladwin, T., Geeraerts, S., Pas, P., Bos, D., Hofstee, M., Durston, S. & Vollebergh, W. (2020). Towards an integrated account of the development of self-regulation from a neurocognitive perspective: A framework for current and future longitudinal multi-modal investigations. *Developmental Cognitive Neuroscience, 45*, 1-9. https://doi.org/10.1016/j.dcn.2020.100829/

Walker, T. (2023, October). Rural schools take on the mental health crisis. *National Education Association (NEA) Today*, 38-42.

Walsh, R. (1983). The consciousness disciplines, *Journal of Humanistic Psychology, 28,* 28-30.

Weerdmeester, J, MJW van Rooij, M., CME Engels, R., & Granic, I. (2020). An integrative model for the effectiveness of biofeedback interventions for anxiety regulation: viewpoint. *Journal of Medical Internet Research, 22(*7).

Weir, K. (2023, January 1st). Psychologists are rebranding the field, expanding the one-time therapy approach. Psychologists are expanding the one-to-one therapy approach to strengthen psychological health across entire population. American Psychological Association, *Monitor of Psychology, 54*(1).

Wiener, N. (1948). *Cybernetics; or control and communication in the animal and the machine.* John Wiley.

Winne, P. (2005). A perspective on state-of-the-art research on self-regulated learning. *Instructional Science, 33*, 559-565. https://doi.org/10.1007/s11251-005-1280-9/

Winne, P., & Perry, N. (2000). *Measuring self-regulated learning.* In Pintrich, P., Boekaerts, M. & Seidner (Eds.), *Handbook of self-regulation* (pp.531-566). Academic Press.

Youth Risk Behavior Survey (2021). *Data Summary & Trends Report: 2011-2021*. https://www.cdc.gov/healthyyouth/data/yrbs/pdf/YRBS_Data-Summary-Trends_Report2023_508.pdf/

Zadina, J. (2023). The synergy zone: Connecting the mind, brain, and heart for the ideal classroom learning environment. *Brian Science, 13*, 1314. https://doi.org/10.3390/brainsci13091314/

Zimmerman, B. (1990). Self-regulated learning and academic achievement. *Educational Psychology, 25*, 3-17. https://doi.org/10.1207/s15326985ep2501_2/

Zimmerman, B. (2000). *Attaining self-regulation: A social cognitive perspective*. In Boekaerts, M., Pintrich, P. & Zeidner, M. (Eds.). Handbook of self-regulation research, and applications, Academic Press.

Zimmerman, B. (2005). Attaining self-regulation: A social cognitive perspective. In M. Boekaerts, P. R. Pintrich, & M. Zeidner (Eds.), *Handbook of self-regulation*, 3-40. Academic Press.

Zimmerman, B. (2008). Investigating self-regulation and motivation: Historical background, methodological developments, and future prospects. *American Educational Research Journal, 45*(1), 166–183. https://doi.org/10.3102/0002831207312909/

Zimmerman, B., & Campillo, M. (2003). Motivating self-regulated problem solvers. In Davidson, J., Sterberg, R. (Eds.), *The Nature of Problem Solving* (233-262). Cambridge University Press.

Zimmerman, B., & Moylan, A. (2009). Self-regulation: Where metacognition and motivation intersect. In Hacer, D., Dunlosky, J., Graesser, A. (Eds.), *Handbook of Metacognition in Education* (229-315), Routledge.

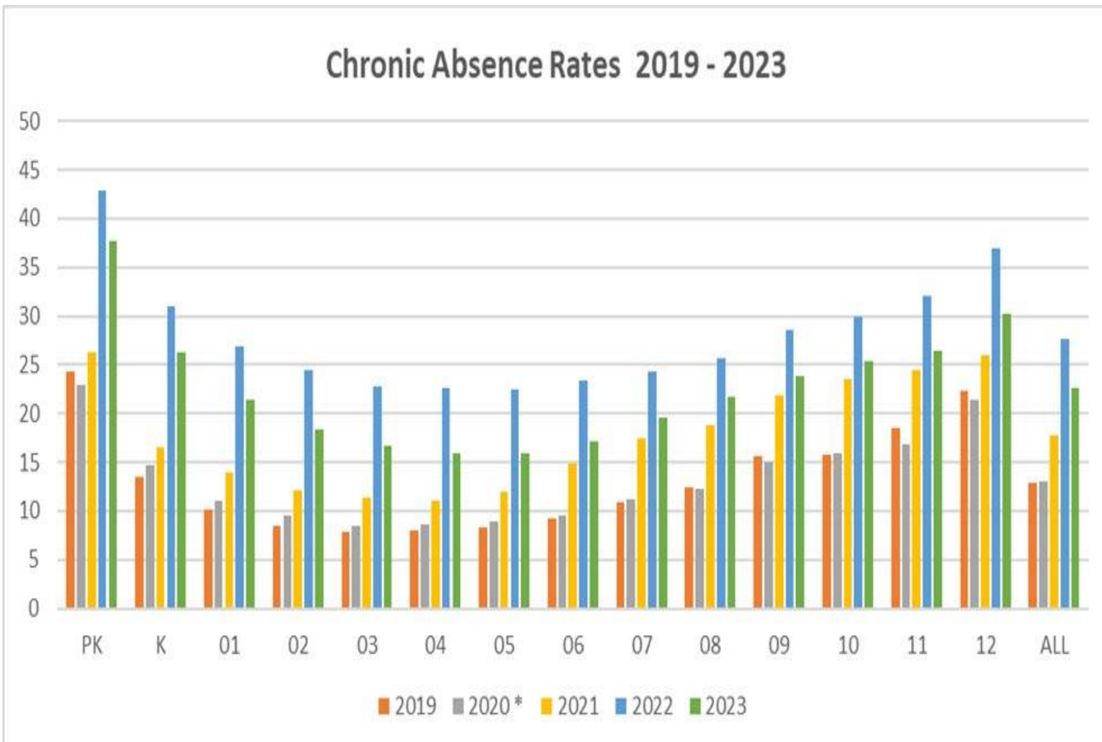
Zimmerman, B., & Schunk, D. (2001). *Self-regulated learning and academic achievement: Theoretical perspectives,* Second Edition. Routledge.

APPENDIX A

Chronic Student Absences

Chronic Student Absences

This chart reflects five years of chronic absenteeism in Massachusetts by grade level. In March 2020, data was reported only through March (due to the school shutdowns from COVID-19). In 2020-2021, schools were operating under a remote and hybrid learning model, and in 2021-2022, schools reopened to in-person learning for all students.



Drysdale, 2023

APPENDIX B

Student Attendance Data

Student Attendance Data

POST-PANDEMIC (2022-2023)

Student Group	Attendance Rate	Average # of Absences	Absent 10 or more days	Chronically Absent (10% or more)	Chronically Absent (20% or more)	Unexcused > 9 days
All Student	95.3	8.3	26.1	9.2	3.2	4.0
Female	95.7	7.7	22.2	6.1	2.7	1.5
Male	94.8	9.0	30.5	12.6	3.8	6.7
Low Income	92.4	13.0	39.0	20.0	8.0	13.0
High Needs	93.2	11.8	39.6	16.1	6.0	10.7
LEP English language learner	95.0	9.1	44.4	11.1	0.0	0.0
Students with disabilities	93.1	12.0	43.4	13.2	6.6	11.8
African American/Black	86.2	24.9	55.6	33.3	33.3	33.3
American Indian or Alaskan Native						
Asian	97.7	4.1	11.1	0.0	0.0	0.0
Hispanic or Latino	92.3	13.2	47.5	20.0	7.5	20.0
Multi-race, non-Hispanic or Latino	93.7	10.4	35.3	17.6	5.9	5.9
White	95.8	7.5	23.3	7.5	2.1	1.9

PRE-PANDEMIC (2018-2019)

Student Group	Attendance Rate	Average # of Absences	Absent 10 or more days	Chronically Absent (10% or more)	Unexcused > 9 days
All Student	95.4	8.0	24.5	10.1	4.6
Male	95.2	8.3	22.6	10.5	5.8
Female	95.6	7.7	26.0	9.7	3.5
Economically Disadvantaged	92.8	12.6	38.8	22.5	11.3
High Needs	93.3	11.5	36.5	22.2	10.3
LEP English language learner					
Students with disabilities	92.6	12.7	42.6	24.6	9.8
Hispanic or Latino	94.8	8.7	40.0	12.0	8.0
Multi-race, non-Hispanic or Latino	93.7	10.8	20.0	10.0	10.0
White	95.5	8.0	24.5	10.1	4.1
Asian	98.7	2.3	0.0	0.0	0.0
African American/Black					
American Indian or Alaskan Native					

Data tables from doe.mass.edu

APPENDIX C

Participant Consents

Participant Consents

Parental Consent Form

Your child has been invited to take
part in a research study on Self Regulated Learning using a technique called Biofeedback.

Biofeedback is used in our daily lives all the time- but most people may not know the name. For example, if your body is feeling warm you might use a thermometer to take your temperature. The results from the thermometer gives you feedback on how your body is feeling in the moment. Knowing this feedback may then help to change your behavior (i.e. if you have a fever, you are then most likely to take a fever-reducer medication to bring it down).

The biofeedback technology that I will be using with your students measures heart rhythms (using an ear clip attached to an IPad) and provides them with the feedback of their heart rate- and with helpful tips on how to breathe at a pace that is best conducive to their learning and focus.

I recently wrote and was awarded a grant
to receive biofeedback technology (Inner Balance: from HeartMath Institute [https://store.heartmath.com/innerbalance]) to use with the
high school students. I plan to teach a group of students how to use the technology as a way to help them better self-regulate (the week of February 26th, 2023). The learning strategy will take less than 5-minutes and will occur at the beginning of their English class for a period of six weeks (March 4th till April 12th).

There will be two classrooms involved in this study. One classroom will receive the biofeedback strategy while the other class will be withheld from the strategy. At the end of the study (returning back from April break) if the students who did not receive biofeedback wishes to receive the intervention, then I would be more than happy to provide them with that opportunity!

In addition to parent/guardian consent, I will be seeking assent from each student. Student participants will be provided with the clear understanding that participation is completely voluntary and that at any time, they have the option to withdraw from the study. There are minimal risks since this intervention is safe and noninvasive. Aside from the brief intervention at the start of class, there will be no interruptions to their learning, routine, or class schedule.
Check out the researched benefits: https://www.heartmath.org/training/child-mental-health/

For a deeper dive, check out the science behind it: https://www.heartmath.org/science/

The school district's identity and student data will remain anonymous throughout the study. Students' data will be collected using a Student ID system that will ensure confidentiality and protection of privacy.

With that said, if school media, newspaper, magazine, or journal publication is interested to document the study using photo images, I have included a request for consent for taking photos of your students in class using the technology. Photography is not required to be a part of the study.

At the end of data collection, all students will be entered into a raffle for a gift card prize. **I am passionate about this project and hope to have the privilege to provide this opportunity to your student!**

If you have any questions or concerns, please feel free to reach out to me directly:

[redacted]

[redacted]

Thank you so much for your time and consideration!!!

Rebecca
Rebecca Henry, Ed.S., LMHC, NCSP, LEP, CIMHP, ABSNP
Licensed School Psychologist
Licensed Mental Health Counselor
Nationally Certified School Psychologist
Licensed Educational Psychologist
Certified Integrative Mental Health Professional
American Board School Neuropsychologist
Doctoral Candidate

1. YOUR NAME: *

____

2. RELATIONSHIP TO CHILD: *

____

3. CHILD'S NAME: *

____

4. DO YOU GIVE CONSENT TO HAVE YOUR CHILD PARTICIPATE IN THIS EDUCATIONAL RESEARCH? *

Check all that apply.

☐ YES I CONSENT: I would like my child to have the opportunity to be a part of this study

☐ NO, I DO NOT CONSENT: I respectfully decline my child's participation in the study

5. USE OF PHOTOGRAPHY:

Check all that apply.

☐ YES, TAKE PHOTOS OF MY CHILD USING THE TECHNOLOGY!

☐ NO, PLEASE DO NOT TAKE PHOTOS OF MY CHILD USING THE TECHNOLOGY.

Student Assent Form

You have been invited to take
part in a dissertation research study using a technique called Biofeedback.

Biofeedback is used in our daily lives all the time- but most people may not know the name. For example, if your body is feeling warm you might use a thermometer to take your temperature. The results from the thermometer gives you feedback on how your body is feeling in the moment. Knowing this feedback may then help to change your behavior (i.e. if you have a fever, you are then most likely to take a fever-reducer medication to bring it down).

The biofeedback technology used in the study measures and provides feedback on heart rates (using an ear clip attached to an IPad)- with helpful tips on how to breathe at a pace that is best conducive to learning and focus.

There will be two classrooms involved in this 6-week study (March 4th till April 12th). One classroom will receive the biofeedback strategy while the other class will be withheld from the strategy. At the end of the study (returning back from April break) the classroom that did not receive biofeedback will be offered an opportunity to receive the intervention. The biofeedback strategy will take less than 5-minutes at the beginning of your English class for a period of six weeks.

Your participation in this research study is entirely voluntary and you can withdraw from this study at any time. There are minimal risks since this intervention is safe and noninvasive. Also, at any time during the intervention period, you may utilize the safeguard resources that the school has available for all students (i.e. school counselor, guidance support, nurse, etc.).

Aside from the brief intervention at the start of class, there will be no interruptions to your learning, routine, or class schedule.
Check out the researched
benefits: https://www.heartmath.org/training/child-mental-health/

For a deeper dive, check out the science behind
it: https://www.heartmath.org/science/
The school district's identity and student data will remain anonymous throughout the study. Students' data will be collected using a Student ID system that will ensure confidentiality and protection of privacy.

With that said, if school media, newspaper, magazine, or journal publication is interested to document the study using photo images, I have included a request for consent for taking photos in class using the technology. Photography is not required to be a part of the study.

At the end of data collection, you will have an opportunity to be entered into a raffle for a gift card prize!

If you have any questions or concerns, please feel free to reach out to me directly:

[redacted]

[redacted]

Thank you so much for your time and consideration!!!

Ms. Henry
Rebecca Henry, Ed.S., LMHC, NCSP, LEP, CIMHP, ABSNP
Licensed School Psychologist
Licensed Mental Health Counselor
Nationally Certified School Psychologist
Licensed Educational Psychologist
Certified Integrative Mental Health Professional
American Board School Neuropsychologist
Doctoral Candidate

1. YOUR NAME: *

____

2. DO YOU ASSENT TO PARTICIPATE IN THIS EDUCATIONAL RESEARCH? *

Check all that apply.

☐ YES I ASSENT: I would like to have the opportunity to be a part of this study

☐ NO, I DO NOT ASSENT: I respectfully decline my participation in the study

3. USE OF PHOTOGRAPHY: *

Check all that apply.

☐ YES, TAKE PHOTOS OF ME WHILE USING THE TECHNOLOGY!

☐ NO, PLEASE DO NOT TAKE PHOTOS OF ME USING THE TECHNOLOGY.

Teacher Consent Participation Form

My name is Rebecca Henry, the school psychologist at [redacted]. I am completing a doctoral dissertation in Educational Psychology. I am writing to ask for your written permission to participate in the following proposed educational research.

You have been invited to take
part in a research study titled "An Investigation of a Biofeedback
Intervention at a Public Secondary School as an In-Classroom Self-Regulated
Learning (SRL) Strategy."

Biofeedback is the process of measuring one's physiological states while providing immediate feedback for the purpose of learning how to change one's physiological activity (Weerdmeester et al., 2020). Many of us already use biofeedback through the use of our smartphones, watches, and other activity-tracking devices.

My interest is to implement a self-administered biofeedback activity with a group of adolescent youth and investigate the potential connection with self-regulated learning. I recently wrote and was awarded a grant to receive biofeedback technology (Inner Balance: from HeartMath Institute [https://store.heartmath.com/innerbalance]) to use with our high school students. My study plans to address biofeedback as a potential self-regulated learning strategy that can be applied in the classroom.
The proposed intervention will be delivered to a Treatment Group and withheld from a Control Group. Student participants selected for the Control Group will be offered the option to receive the biofeedback intervention following the data collection.

Students selected for the Treatment Group will engage in the biofeedback activity for less than 5 minutes at the start of class. The activity runs on an App through an iPad and shows a pleasant visual color image that teaches the students how to control their breathing in an effective rhythm that calms their mind and body. There is evidence-based research that shows how biofeedback supports focus and attention.

This will be a 6-week intervention: February 26th to April 12th, 2024

There are minimal risks expected. The biofeedback sensor is a safe ear clip that secures to the student's ear lobe. The sensor monitors and reads the student's heartbeat and pulse (similar to how a FitBit or AppleWatch measures and tracks physical activity). Biofeedback is safe and noninvasive. While extremely rare, it is possible that the ear clip may cause discomfort (it clips to the ear with padded support, similar to how a "clip-on earring" attaches to the ear). Students wear the ear clip for less than 5 minutes while using the biofeedback tool.

Biofeedback has robust evidence-based benefits expected to support student learning. **The Inner Balance™ wired sensor** and app teach how to **shift from stress and frustration to balance and resilience** with real-time feedback based on one's own heart rhythm. The biofeedback technology provides a visual image of "real-time" heart rhythms and is intended to help the students train their heart rhythms to stabilize through guided practice.
Check out the researched benefits: https://www.heartmath.org/training/child-mental-health/

For a deeper dive, check out the science behind it: https://www.heartmath.org/science/
The school district's identity, and teacher & student data will remain anonymous throughout the study. Students' data will be collected using a Student ID system that will ensure confidentiality and protection of privacy.

In addition to parent/guardian consent, I will be seeking assent from each student. Student participants will be provided with the clear understanding that participation is completely voluntary and that at any time, they have the option to withdraw from the study.

At the end of data collection, students will be entered into a raffle for a gift card prize.

If you have any questions or concerns, please feel free to reach out to me directly:

rhenry@ipsk12.net

978.356.3137 ex. 2154

Thank you so much for your time and participation!!!

Rebecca
Rebecca Henry, Ed.S., LMHC, NCSP, LEP, CIMHP, ABSNP
Licensed School Psychologist
Licensed Mental Health Counselor
Nationally Certified School Psychologist
Licensed Educational Psychologist
Certified Integrative Mental Health Professional
American Board School Neuropsychologist
Doctoral Candidate

1. YOUR NAME: *

____

2. YOUR TITLE *

____

3. DO YOU GIVE CONSENT TO PARTICIPATE IN THIS EDUCATIONAL RESEARCH? *

Check all that apply.

- [ ] YES I CONSENT: I would like the opportunity to be a part of this study
- [ ] NO, I DO NOT CONSENT: I respectfully decline my participation in the study

APPENDIX D

Permission to Use Inner Balance Technology

Permission to Use Inner Balance Technology

HeartMath Institute

December 12, 2023

Rebecca Henry
25 Stonebridge Rd
Groveland MA 01834

Dear Rebecca,

This letter documents our willingness to help you with your upcoming study with high school students using the Inner Balance technology. As a nonprofit, we commonly help researchers and educators measure resilience and well-being using the various metrics of our technology and their heart rate variability measures.

Included in our offer is tutorial guidance on how to use the technology and best practices.

Please do not hesitate to reach out should you have further questions.

Sincerely,

Jeff Goelitz

Jeff Goelitz
Director of Education
jgoelitz@heartmath.org
831-338-8713

Jeff Goelitz
Director of Education
(831) 338-8713 | **jgoelitz@heartmath.org**
Click to schedule a call
HeartMath Institute

APPENDIX E

Permission to Use Motivated Strategies for Learning Questionnaire (MSLQ)

Permission to Use Motivated Strategies for Learning Questionnaire

From: Daniel Hartlep dhartlep@umich.edu
Subject: Re: Formal request to use MSLQ
Date: November 27, 2023 at 3:30:58 PM
To: Rebecca Henry rebecca.henry@me.com
Cc: mslq@umich.edu

Hello yes you may use the mslq as it is in the public record. All we ask is that it is properly cited in your work.

Thank you and good luck!

Daniel Hartlep *(he/him/his)*
Program Coordinator | Combined Program in Education & Psychology
(734) 763-0680 | dhartlep@umich.edu
610 E. University Ave | Room 1413
MARSAL FAMILY SCHOOL OF EDUCATION

On Wed, Nov 22, 2023 at 9:54 AM Rebecca Henry <rebecca.henry@me.com> wrote:

> To the National Center for Research at the University of Michigan:
>
> My name is Rebecca Henry, and I am a psychologist at a public secondary school in the northeast region of Massachusetts. I am currently working on my dissertation proposal and would like to implement the Motivated Strategies for Learning Questionnaire (MSLQ) as a part of my research of self-regulation learning. I have reviewed the instrument's manual which indicates that the MSLQ is in the public domain. I am reaching out to confirm that I have permission to use the MSLQ instrument in my study. Your response will be shared with my proposal and will aid in the progress of my study. Thank you, in advance, for your time.
>
> Sincerely,
> Rebecca Henry
>
> Rebecca Henry, Ed.S., LMHC, NCSP, LEP, CIMHP, ABSNP
> Licensed School Psychologist
> Licensed Mental Health Counselor
> Nationally Certified School Psychologist
> Licensed Educational Psychologist
> Certified Integrative Mental Health Professional
> American Board School Neuropsychologist
> Doctoral Candidate

APPENDIX F

Metacognitive Self-Regulation (MSR) Subscale

Metacognitive Self-Regulation (MSR) Subscale

Please enter your STUDENT ID (associated to this research study) *

Your answer

QUESTION #1 *
During class time I often miss important points because I'm thinking of other things.
(*scale reversed)

	1	2	3	4	5	6	7	
VERY TRUE OF ME	○	○	○	○	○	○	○	NOT AT ALL TRUE OF ME

QUESTION #2 *
When reading for this course, I make up questions to help focus my reading.

	1	2	3	4	5	6	7	
NOT AT ALL TRUE OF ME	○	○	○	○	○	○	○	VERY TRUE OF ME

QUESTION #3 *
When I become confused about something I'm reading for this class, I go back and try to figure it out.

	1	2	3	4	5	6	7	
NOT AT ALL TRUE OF ME	○	○	○	○	○	○	○	VERY TRUE OF ME

QUESTION #4 *
If course materials are difficult to understand, I change the way I read the material.

	1	2	3	4	5	6	7	
NOT AT ALL TRUE OF ME	○	○	○	○	○	○	○	VERY TRUE OF ME

QUESTION #5 *
Before I study new course material thoroughly, I often skim it to see how it is organized.

	1	2	3	4	5	6	7	
NOT AT ALL TRUE OF ME	○	○	○	○	○	○	○	VERY TRUE OF ME

QUESTION #6 *
I ask myself questions to make sure I understand the material I have been studying in this class.

	1	2	3	4	5	6	7	
NOT AT ALL TRUE OF ME	○	○	○	○	○	○	○	VERY TRUE OF ME

QUESTION #7 *
I try to change the way I study in order to fit the course requirements and instructor's teaching style.

	1	2	3	4	5	6	7	
NOT AT ALL TRUE OF ME	○	○	○	○	○	○	○	VERY TRUE OF ME

QUESTION #8 *
I often find that I have been reading for class but don't know what it was all about.
(*scale reversed)

	1	2	3	4	5	6	7	
VERY TRUE OF ME	○	○	○	○	○	○	○	NOT AT ALL TRUE OF ME

QUESTION #9 *
I try to think through a topic and decide what I am supposed to learn from it rather than just reading it over when studying.

	1	2	3	4	5	6	7	
NOT AT ALL TRUE OF ME	○	○	○	○	○	○	○	VERY TRUE OF ME

QUESTION #10 *

When studying for this course I try to determine which concepts I don't understand well.

	1	2	3	4	5	6	7	
NOT AT ALL TRUE OF ME	◯	◯	◯	◯	◯	◯	◯	VERY TRUE OF ME

QUESTION #11 *

When I study for this class, I set goals for myself in order to direct my activities in each study period.

	1	2	3	4	5	6	7	
NOT AT ALL TRUE OF ME	◯	◯	◯	◯	◯	◯	◯	VERY TRUE OF ME

QUESTION #12 *

If I get confused taking notes in class, I make sure I sort it out afterwards

	1	2	3	4	5	6	7	
NOT AT ALL TRUE OF ME	◯	◯	◯	◯	◯	◯	◯	VERY TRUE OF ME

APPENDIX G

Institutional Consents

Institutional Consents

[redacted] Public Schools
[redacted] *High School*
[redacted] MA [redacted]
TELEPHONE: [redacted]
Fax: [redacted]

November 22, 2023

Attention:
Dr. Brian Blake, Superintendent of Schools
Mr. Jonathan Mitchell, High School Principal

Dear Dr. Blake and Mr. Mitchell.

I am writing to request site approval to conduct an empirical study for my dissertation research on "An Investigation of a Biofeedback Intervention at a Public Secondary School as an In-Classroom Self-Regulated Learning (SRL) Strategy."

The proposed study plans to investigate a biofeedback intervention as an in-classroom self-regulated learning strategy by testing statistical differences on two dependent variables: 1) *Self-Regulated Learning,* and 2) *Time-On-Task.* The proposed intervention will be delivered to a Treatment Group and withheld from a Control Group. Group differences will be measured. Students in the Control Group will be offered an opportunity to receive the biofeedback activity following the data collection period.

Based on evidence-based research on biofeedback technology, a positive relationship is predicted with Self-Regulated Learning and Time-On-Task. Moreover, the literature charges that students who are self-regulated learners are more motivated to learn and have strong self-efficacy, and therefore, it is further hypothesized that they may spend more time in the classroom on task.

Biofeedback is the process of measuring one's physiological states while providing immediate feedback for the purpose of learning how to change one's physiological activity (Weerdmeester et al., 2020). Many of us already use biofeedback through the use of our smartphones, watches, and other activity-tracking devices. My interest is to implement a self-administered biofeedback activity with a group of adolescent youth (two sections of the same co-taught junior English class) and investigate potential connections with self-regulated learning.

The aftermath of the pandemic has exacerbated students' difficulties with executive functioning (a major component of self-regulated learning) due to an increase in mental health challenges (Zadina, 2023). Furthermore, research has specifically illustrated the critical stage of the adolescent brain and the significant developmental changes that occur, which make learning self-regulated skills extremely important for this age group (Murray & Rosanbalm, 2017). Literature is calling upon future research to emphasize the use of biofeedback techniques in schools to help students become better self-regulated learners.

Self-Regulated Learning (SRL) affects academic performance and has been thought of as a learning process that students undergo to help control and direct their learning (Akhtar & Mahmood, 2013; Santrock, 2006; Bembenutty, 2005). NPR (2023) reported on "All Things Considered" that since the pandemic school absenteeism has increased, noting that in Spring 2022 16 million U.S. students were considered chronically absent, compared to the pre-pandemic figure of 8 million students. Why are students avoiding school? Are they struggling to be resilient? For this reason, SRL has become an important topic in educational research (Steffen, 2006). Ormond (2020) charges that SRL is "a general ability to take charge of one's behaviors, for instance by keeping counterproductive impulses in check" (p.383). The problem adolescent students are up against regards their dysregulated brain development (the part of their brain most responsible for regulation [frontal lobe] is not fully developed into their mid-20s). Therefore, this supports the idea that self-regulated learning is not a natural learning process, but instead, it is a *learned skill that needs to be taught.* Adolescents need to be taught strategies to effectively engage in self-regulated learning.

I recently wrote and was awarded a grant to receive biofeedback technology (Inner Balance: from HeartMath Institute [https://store.heartmath.com/innerbalance]) to use with our high school students. I have informally discussed my intervention with two teachers (general education and special education) who co-teach two sections of a junior English class. A pre-test/post-test using the Metacognitive Self-Regulation Subscale of the Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich, 1991) will measure self-regulated learning. This tool is one of the most widely used measures of self-regulated learning. Additionally, I will collect data on "Time-On-Task." This information would be collected by the already established check-in/check-out system that is currently being used when students leave the classroom (measured in minutes).

Consent forms will be provided to the participant's parents/guardians and will include a concise and focused presentation of key information as it pertains to the Common Rule requirements as set forth by the IRB process for research with human subjects. Given that the student participants are under the legal age of eighteen, Assent Forms will be provided to the student participants with the clear understanding that participation is completely voluntary and that at any time, they have the option to withdraw from the study. There are minimal risks expected and benefits predicted to support student learning. At the end of data collection, students from the Treatment Group and Control Group will be entered into a raffle for a gift card prize.

The school district, teacher, and student identity will remain anonymous throughout the study. Students' data will be collected using a Student ID system that will ensure confidentiality and protection of privacy.

Thank you in advance for your time and consideration of my proposed research study.

Rebecca Henry

Rebecca Henry, Ed.S., LMHC, NCSP, LEP, CIMHP, ABSNP
Licensed School Psychologist
Licensed Mental Health Counselor
Nationally Certified School Psychologist
Licensed Educational Psychologist
Certified Integrative Mental Health Professional
American Board School Neuropsychologist
Doctoral Candidate

[redacted] Public Schools

High School [redacted]

November 22, 2023

Rebecca Henry

[redacted]

Dear Rebecca Henry,

I am writing to support your research study, "An Investigation of a Biofeedback Intervention at a Public Secondary School as an In-Classroom Self-Regulated Learning (SRL) Strategy." The [redacted] Public Schools are very supportive of research efforts dedicated to improving the delivery of instruction and self-regulated learning to all [redacted] students.

To that end, [redacted] High School will permit you to conduct your research beginning the week of February 26th through April 12th, 2024, in an effort to support our student needs.

We look forward to learning the results of your research.

Sincerely,

Jonathan Mitchell
Principal

Brian Blake
Superintendent

APPENDIX H

Biofeedback Training Workshop

BIOFEEDBACK TRAINING WORKSHOP

DAY 1

EQUIPMENT SET UP & INTRODUCTION

1) Pass out equipment to students. Each student gets their own **iPad**, Inner Balance Heartmath Pulse **Sensor**, and **AirPods.**

2) Instruct students to check for a reliable internet connection, connect the sensor to the iPad and open the Inner Balance App.

3) Have students follow the iPad's instructed prompts:
   - *Would you like to use Bluetooth?* (Select "YES")
   - *Push notifications?* (Select "YES")
   - *Inner Balance would like to communicate with HeartMath Pulse Sensor...* (Select "ALLOW")
   - *Create an account and password.*

4) Provide the class with a guided tour through the Inner Balance App. (Use a SmartBoard or projector to demonstrate each introductory lesson visually. Go through each lesson while students listen and locate via their own devices.)
   - WELCOME TO INNER BALANCE
   - INNER BALANCE APP OVERVIEW
   - PRACTICE- THE SESSION VIEW
   - DEEPER PRACTICE- THE ADVANCED SCREEN
   - REVIEW- HISTORY AND PROGRESS
   - JOURNALS-ANNOTATE YOUR JOURNEY
   - HEARTCLOUD- FEATURES OF THE FREE SERVICE
   - SETTINGS- CUSTOMIZE YOUR EXPERIENCE
     - Under Settings: make sure students set their sessions to "5-minutes."

DAY 2

TRAINING, NORMS, & EXPECTATIONS

1) Welcome the class with a brief review of the previously covered set-up and introductory information.

2) State norms for respectful behavior, student's privacy, and readdress student's rights to withdraw from study at any time.

3) Show the students the step-by-step plan and expectations for the next 6-weeks:
   a. Come into class and put your belongings down.
   b. Go over to the charging station and take your assigned iPad, Sensor, AirPods, and Tracker Sheet.
   c. Return to your seat and quietly begin a session.
   d. Once done, quietly return and plug in your equipment to the charging station. Return Tracker Sheets in the assigned bin.

4) Hand out Tracker Sheets and demonstrate how to complete them (via Smartboard or projector) while students follow along.

5) Describe the "why" behind biofeedback by watching these three short videos together as a class (each is about 2 minutes long).
   a. The Science of Heart Math
      https://www.youtube.com/watch?v=VsFBvvi3xOQ
   b. Heart & Brain Connection
      https://www.youtube.com/watch?v=WhxjXduD8qw
   c. Heart-Focused Breathing Demo
      https://www.youtube.com/watch?v=JxNjw3bcfVo

6) Finally, the training day ends with a practice session. Students practice how to get their equipment from the charging station, conduct a session, and return their equipment and Tracker Sheets.

7) "Question & Answer" time. Ensure students are comfortable using their equipment and feel ready to begin. Provide students with the researcher's contact information for concerns, questions, or support.

APPENDIX I

Student Tracker Worksheet

Student Tracker Worksheet

TRACKER WORKSHEET

STUDENT ID______________

TODAY'S DATE
LENGTH OF TIME
LEVEL (1-4)
AVERAGE COHERENCE SCORE
ACHIEVEMENT POINTS

Achievement Points: are the sum of coherence scores added up every 5 seconds. At the end of the session, you will see your total number of achievement points.

Coherence Score: is the average current score tallied every 5 seconds, whether in the red, blue or green zone. At the end of the session, you will see your average coherence score.

COHERENCE CHALLENGE
Write a Goal: Write down a simple goal where you can apply the heart-focused breathing strategy to a specific situation or challenge: I will use the heart-focused breathing________________________________

APPENDIX J

Student Debrief Form

Student Tracker Worksheet

STUDENT DEBRIEF FORM

* Indicates required question

1. WHAT IS BIOFEEDBACK? *

2. TECHNOLOGY: *

   WAS THE BIOFEEDBACK EQUIPMENT EASY TO USE?

   Check all that apply.

   - [ ] YES
   - [ ] NO

3. TECHNOLOGY: *

   IF NO, PLEASE EXPLAIN WHY:

4. DID YOU ENJOY DOING THE BIOFEEDBACK STRATEGY BEFORE THE START OF CLASS? *

   Check all that apply.

   - [ ] YES
   - [ ] NO

5. IF YES, WHAT DID YOU ENJOY? PLEASE SHARE ANY PERSONAL OBSERVATIONS OR CHANGES WITHIN YOURSELF? *

6. IF NO, WHY DID YOU NOT ENJOY IT? *

7. DID YOU USE THE STRATEGY OUTSIDE OF THE SCHEDULED IN-CLASS TIME? *

Mark only one oval.

- YES
- NO

8. IF YES, WHEN AND WHERE DID YOU USE IT? *

9. IN YOUR EXPERIENCE, DO YOU FEEL THAT HIGH SCHOOL STUDENTS SHOULD HAVE ACCESS TO THIS BIOFEEDBACK STRATEGY ? *

Check all that apply.

- [ ] YES
- [ ] NO

10. OVERALL, HOW WOULD YOU SAY YOUR EXPERIENCE WAS PARTICIPATING IN THIS STUDY? ANYTHING YOU WOULD LIKE ME TO KNOW THAT WOULD HELP ME BETTER UNDERSTAND YOUR EXPERIENCE AND THOUGHTS ABOUT USING BIOFEEDBACK STRATEGIES IN SCHOOL? *