Implications of Individuals with Music Learning Experience Using a Segmented Multimedia Lesson in a Non-Music Discipline

Cheryl Farren Tkacs

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IMPLICATIONS OF INDIVIDUALS WITH MUSIC LEARNING EXPERIENCE USING A SEGMENTED MULTIMEDIA LESSON IN A NON-MUSIC DISCIPLINE

A Dissertation
Submitted to the School of Education

Duquesne University

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By
Cheryl Farren Tkacs

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IMPLICATIONS OF INDIVIDUALS WITH MUSIC LEARNING EXPERIENCE
USING A SEGMENTED MULTIMEDIA LESSON IN A NON-MUSIC DISCIPLINE

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ABSTRACT

IMPLICATIONS OF INDIVIDUALS WITH MUSIC LEARNING EXPERIENCE USING A SEGMENTED MULTIMEDIA LESSON IN A NON-MUSIC DISCIPLINE

By
Cheryl Farren Tkacs

December 2022

Dissertation supervised by Misook Heo

The purpose of this study was to investigate how prior music learning experience relates to learning with multimedia resources in non-music disciplines. Specifically, whether years of music learning experience, type of music learning experience, or type of multimedia were associated with task scores and task duration in a non-music discipline. The study revealed the transferable benefits of music learning experience to learning outcomes in other disciplines. Encouraging music studies as part of the base curriculum is thus strongly encouraged. However, as years of music learning and the presence or absence of segmenting in multimedia learning resources were not found to associate with learning outcomes, it may be worthwhile to examine other potential factors that are developed as a byproduct of music learning.
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Chapter I

Introduction

Humans are natural-born learners and have a voracious appetite for information (Dewey, 2004; Robinson & Aronica, 2015). It is, however, only within the last century that research on how humans learn has been conducted (Cordasco, 1976). The 20th century ushered in a multitude of studies conducted by educators and psychologists on how individuals process information (Cook & Klipfel, 2015; Seidel & Shavelson, 2007).

An individual receives information from external sources, determines the relevance of the stimuli and temporarily stores information in working memory, draws connections to prior knowledge, and stores this integrated information in long-term memory where it can later be retrieved (Sweller et al., 2011b; Zull, 2012). While working memory is critical in performing tasks such as learning, comprehension, and logical thinking (Baddeley & Hitch, 1974; Baddeley & Hitch, 1974; Miller et al., 1960), it can only process a finite amount of information (Bassett et al., 2009; Crouzevialle & Butera, 2013; Hampson et al., 2006; Paas & Ayres, 2014; Sweller et al., 1998).

The amount of working memory resources that are used during the processing of new information relates to cognitive load (Sweller et al., 2011b). While some cognitive processes are associated with the level of the natural complexity of a task (intrinsic load), other processes are associated either with complexity caused by inappropriate instructional designs (extraneous load) or with the effort to construct accurate mental models and schemas (germane load) (Sweller, 1994). As these types of cognitive load are additive, yet working memory is limited, Mayer (2014c) in his studies regarding multimedia learning suggested various instructional design approaches to reduce the
overall cognitive load: reduce extraneous cognitive load, manage intrinsic cognitive load, and increase germane cognitive load (Mayer, 2002a, 2003; Mayer et al., 2001; R. Moreno & Mayer, 2000; Spanjers et al., 2011). Reducing extraneous cognitive load aims to free working memory resources to deal with the germane load as it constructs new connections when processing incoming stimuli. Providing only the relevant materials to the learner, promoting focus of attention, limiting redundant information, and locating related words and pictures close by are examples of reducing extraneous cognitive load (Mayer & Fiorella, 2014). Efficiently managing intrinsic cognitive load can be accomplished by providing instructional material using multiple modalities and breaking down instructional material into learner-paced, smaller chunks thus easing the load on working memory (Mayer & Pilegard, 2014).

**Statement of Problem**

Instructional strategies for multimedia learning may differ based on factors such as individuals’ prior knowledge. For example, novice learners often see new information as random bits of data due to a limited understanding of the content and the lack of knowledge of how that discipline is organized (Bruer, 1993; Clark et al., 2006; Hmelo-Silver & Pfeiffer, 2004). These learners have to search for a solution using trial and error (Kalyuga, 2013) creating an unnecessary burden on cognitive load thereby impeding the learning process (Baddeley & Hitch, 1974; Sweller, 1988). Conversely, learners with prior experience are more resourceful, knowledgeable, strategic, purposeful, and motivated in their approach to learning new information (Bernacchio & Mullen, 2007; Clark et al., 2006; King-Sears, 2009). These individuals can connect new knowledge through networks of information stored in memory, which facilitates learning (Baddeley
In line with this model, Mayer (2014c) suggests that individuals learn more efficiently if instructional resources are constructed using both words and pictures. Empirical evidence supporting this theory suggests that well-designed instructional resources (e.g., providing only relevant materials to the learner, grouping related information, promoting focus of attention, etc.) can help learners better process information (Jonides et al., 2008). The effectiveness of multimedia in learning has been examined in multiple disciplines, most notably including areas of science (e.g., Al-Hariri & Al-Hattami, 2017; Chang & Hsu, 2010), mathematics (e.g., Ashcraft & Krause, 2007; Bissell, 2012; Liu, 2013), engineering (e.g., Jiang, 2008; Kuznetsov, 1996; Stelzer et al., 2010), as well as language (e.g., Chapelle, 1998; Plass & Jones, 2005; Schmid, 2008) and social sciences (e.g., De Westelinck, et al., 2005; Fletcher & Tobias, 2005). Multimedia research in other fields, such as music, has not been as well explored.

Music involves a blend of almost every cognitive function (Zatorre, 2005). Researchers identify recognizable changes in the information and memory processing of music learners (Degé et al., 2011; Moreno, 2009; Tierney et al., 2013). For example, music learners are trained to chunk or segment musical elements into smaller units that are of a cognitively manageable size as they perfect difficult passages (Chi et al., 1982; Ericsson et al., 1993; Ericsson et al., 2007). Can these abilities that music learners have acquired in the process of music learning be transferrable to learning in other disciplines? The literature responding to this question is limited and thus offers a unique research opportunity.
Purpose of Study

The purpose of this study is to investigate how prior music learning experience relates to learning with multimedia resources in non-music disciplines. Music learning can occur in various settings, such as schools, private lessons, self-taught, and community music groups. Learning music offers individuals unique opportunities to train important cognitive skills (e.g., segmenting or chunking).

This study will investigate whether cognitive skills trained via music learning transfer to a non-music discipline by uncovering the association, or the lack thereof, that varying degrees of prior music learning, types of the music learning experience, and multimedia learning resource types are associated with student learning performance. It is anticipated that an individual’s music learning experience will relate to different learning outcomes. The results could validate or conflict with the expertise-reversal effect that occurs when experts utilize segmented multimedia instruction. The ability to generalize these assumptions as they pertain to learning performance will add to the literature relating to the transference of learning strategies across disciplines.

Research Questions and Hypotheses

The main research question guiding the current study is how music learning experience predicts learning with multimedia in non-music disciplines. More specifically, the current study will investigate the following two, main research questions:

RQ1: To what extent do years of music learning experience, type of music learning experience, or type of multimedia in terms of segmentation relate to task scores in a non-music task?
RQ2: To what extent do years of music learning experience, type of music learning experience, or type of multimedia in terms of segmentation predict task duration in a non-music task?

By responding to these two main research questions, the following sub-questions will likewise be addressed:

1. How do the years of prior music learning predict learning, measured by task score in multimedia instruction?
2. How do the years of prior music learning predict learning, measured by task duration in multimedia instruction?
3. How does the type of prior music learning predict learning, measured by task score in multimedia instruction?
4. How does the type of prior music learning predict learning, measured by task duration in multimedia instruction?
5. How does the type of multimedia in terms of segmentation predict learning, measured by task score?
6. How does the type of multimedia in terms of segmentation predict learning, measured by task duration?

To respond to the two, aforementioned main research questions, the following null hypotheses are proposed:

$H_{01}$: Years of music learning experience, type of music learning experience, or type of multimedia in terms of segmentation are not related to task scores in a non-music task.
H₀²: Years of music learning experience, type of music learning experience, or type of multimedia in terms of segmentation are not related to task duration in a non-music task.

The alternative hypotheses, corresponding with these null hypotheses are as follows:

H₁: Years of music learning experience, type of music learning experience, or type of multimedia in terms of segmentation are related to task scores in a non-music task.

H₂: Years of music learning experience, type of music learning experience, or type of multimedia in terms of segmentation are related to task duration in a non-music task.

**Significance of Study**

This study hopes to provide insight into how individuals with music learning experience transfer their learning strategies (e.g., chunking and segmenting) to the acquisition of new knowledge using multimedia learning resources in non-music disciplines. Evidence suggests that the longer a student studies music, the higher their test scores are in mathematics, English, and science (Guhn et al., 2019). Data from this study will provide insights into the potential reasons musical training transfers to learning with multimedia in other disciplines.

Investigating the relationship between the segmenting strategies used by music learners and the possible transfer of that learned cognitive ability could provide effective, constructive, and long-term strategies that can aid in managing cognitive load and the assimilation and retrieval of new knowledge. Expectations are that the data gleaned from this research could have broader pedagogical implications with the potential to bolster
arguments for encouraging music studies as part of the curriculum to promote adaptive learning strategies, which may transfer to other disciplines.

**Delimitations of the Study**

This study has limited the focus of the research to manage time constraints and access to participants within the parameters of the questions being investigated. Participants are recruited from local universities in western Pennsylvania and not the general population of the area; the group is comprised of learners 18 years of age and older. Participants in the study will need to have access to a computer with web access. No hardware or software will be needed or provided. Another delimitation of this research is the material used for the study. For this study, a STEM subject (science) was chosen to provide a contrast in subject matter to music learning (arts). In future research, a non-STEM discipline could be chosen to compare findings to determine whether music learners find it easier to transfer their strategies in STEM or non-STEM subjects. The content in this study, the importance of carbon in the oceans, was used as a leveling measure providing a subject area that was not too difficult or well-known to most participants thereby keeping any frustration level to a minimum as learners progress through the lesson and assessment. The research question has been refined to identify how music learners approach and acquire new knowledge when using segmented and non-segmented multimedia instructional material. As such and working within time, population and creative commons license constraints, participants will access the same lesson in a segmented and non-segmented multimedia instructional form. Finally, while the pre-survey asks participants to identify gender identity and discipline major, they will
not be included in the analyses of data for this study but may be reviewed as part of a later study.
Chapter II

Literature Review

During the 20th century, educators and psychologists focused on research on how information could be presented, understood, and retained based on the psychology of learning (Palmer et al., 2001). A partnership between education and psychology has provided educators with a means of describing, understanding, and measuring the learning process (Zimmerman & Schunk, 2003). Studies in cognitive psychology apply to a broad range of higher mental processes including memory, attention, perception, problem-solving, and mental imagery (Bruning et al., 2004). For effective, efficient, and hypothetically long-lasting learning, educators need to consider the cognitive processes of learners (Greeno et al., 1996; Khalil & Elkhider, 2016).

The review of literature in this chapter provides the foundations on which this study is built. It covers historical and current research on topics beginning with learning theories that were developed to provide explanations on how humans respond, change, and adapt to stimuli. It discusses research on human memory that has provided insight for educators to understand the learning process and explores instructional methods (both teacher-centered and learner-centered) that were implemented to provide the best learning experience for students. This chapter concludes with a review of the current research in multimedia learning, how multimedia instructional material aligns with the theories and instructional approaches, and the disciplines used in those studies focusing on music as a unique discipline in multimedia learning.
Learning Theories in the Era of Digital Multimedia

Research conducted during the 20th century resulted in the development of learning theories. Among the resulting theories, the most prominent or notable theories include behaviorism, cognitivism, constructivism, and connectivism. Each has its relevance and importance in explaining the way people learn. As technology advanced and became prominent in the classroom, guiding principles were developed connecting how individuals learn and process new information and how digital multimedia can benefit instruction (Mayer, 2014a). The combination of digital multimedia with sound pedagogical practices can be a determining factor in the value of learning with instructional multimedia (Dede, 1992; Resnick, 1998; Resnick et al., 1999; Soloway et al., 1999; Watters, 2014). The following subsections examine the theories of behaviorism, cognitivism, constructivism, and connectivism and their application as applied in an era of digital learning.

Behaviorism

Behaviorism is an approach to understanding learning by relying on observable behaviors (Skinner, 1974). Behaviorism theory assumes that learning takes place as a result of an individual modifying their behavior in response to reinforcement provided by the teacher (Fontana, 1984; Schunk, 2008). This stimulus (reinforcement) and response (modified behavior) idea, which was initially observed in research with animals (Moore, 2011; Skinner, 1974), was posited to similarly apply to human learning behavior. This gave rise to the idea of positive and negative reinforcement being an effective tool for learning and behavior modification (Geary & Berch, 2016; Schunk, 2008; Skinner, 1974).
Behavioral modification strategies (i.e., positive or negative reinforcement) include praise, good marks, or punishment for poor performance or inappropriate behavior (Fontana, 1984; Skinner, 1954, 1974). The learner receives this reinforcement, conveyed by the teacher, in conjunction with learning content (i.e., new information) (Fontana, 1984; Geary & Berch, 2016). The teacher creates the learning environment (e.g., direct instruction) and is responsible for the content, how it is delivered, and the assessment of whether learning has occurred (McManus, 2001; Wingfield & Black, 2005). While behavioral modification strategies remain common in modern educational environments (Harrington & Zakrajsek, 2017; Paris, 2016), they are not without their critics.

With an emphasis on the role of the teacher, behaviorism does not promote diverse interactions between the teacher and the learner, the learner and the learner, and the learner and the content (Brown, 2003; Chall, 2000; Fontana, 1984; Pierce & Kalkman, 2003). Behaviorism is result-oriented (Fontana, 1984; Woollard, 2010) and thus is less suitable for understanding the changes in how a learner thinks. It does not allow for consideration of individual differences in learning abilities or the cognitive processes involved in learning (Baum, 2017; Skinner, 1954; Woollard, 2010). In response to the shortcomings of behaviorism, especially the primary focus on learning outcomes and the lack of learners’ active participation, newer approaches toward learning have emerged.

However, that is not to say that are no elements of behaviorism that cannot be applied to multimedia instruction. Many of the characteristics of the behaviorist theory were used as a design basis for multimedia instructional material or computer-based
learning by Skinner himself (Skinner, 1958). With an emphasis on observable and measurable outcomes, multimedia lessons that are designed for preassessment, drill and practice, give the learners feedback for reinforcement, or include simulations for mastering basic steps, are all implementations of the behaviorist theory using digital methods of delivery (Ertmer & Newby, 2013). Behaviorist theory serves as a framework for basic multimedia instruction.

**Cognitivism**

Cognitivism, in contrast to behaviorist theory, asserts that individuals need to be active participants in the learning process (Ashman & Conway, 2002; Mandler, 2002; Masson, 2014). Cognitivism asserts that learning is a process that is dependent on what a learner already knows (prior knowledge) and how new information is received, processed, organized, and integrated (Piaget, 1964). It is therefore important that the teacher understands what prior knowledge their learners have before instruction begins.

The role of the teacher in cognitivist philosophy is to facilitate learners to make connections to their prior knowledge (Ashman & Conway, 2002; Fischer, 2009). This may include identifying the skills and knowledge that will either promote or impede learning, encouraging student engagement, and fostering critical thinking processes. Learners are led to refine their thinking and come to their conclusions as to where they have made their mistakes thus taking a more active role in their learning (Ashman & Conway, 2002; Bandura, 1986; Mandler, 2002). Prior knowledge, or lack of, can have an important effect on the learner’s interpretation and understanding of new information (Graf et al., 2009; Lasry et al., 2014). Accurate assessment of prior knowledge can minimize the learners’ misinterpretations, thereby facilitating the ease of processing new
information. When prior knowledge is assumed in the instruction and there are gaps in the information, the connection, storage, and application of knowledge, learning is hindered (Chi et al., 1988; Chi et al., 1982).

Instructional strategies such as feedback, pre-assessment of learners, and task analysis that have been advocated by behaviorists are also utilized by cognitivists when implementing multimedia content in instruction. The difference lies in the reasons for the strategy: behavior modification versus guiding and supporting the learner (Ertmer & Newby, 2013). The cognitivist theory is best illustrated in today’s classrooms through the use of educational computer games, information mapping tools, research-based assignments, and interactive software and whiteboards (Clark & Harrelson, 2002). Multimedia instruction simplifies the instruction into basic segmented steps that eliminate extraneous information aiding the learner in assimilating new information without stressing the cognitive functions (Ausburn & Ausburn, 1978; Van Merriënboer & Sweller, 2005).

Cognitivists suggest that instructional practices alone do not fully account for learning nor do they explain how an individual interacts with content and makes connections between existing concepts and new knowledge (Mandler, 2002). Consideration of the learner’s thought processes and the role of their beliefs, attitudes, and values have led to an expansion of the fundamental idea of cognitivism leading to the theory of constructivism (Murphy, 2014).

**Constructivism**

Constructivist theory suggests that learners build their understandings and knowledge through direct experience and reflection (Bruning et al., 2004; Schunk, 2008).
Capitalizing on prior knowledge to construct new knowledge and interpretations (Brooks & Brooks, 1999), constructivists further suggest that individuals will learn more if the information is personally meaningful to them (Brooks & Brooks, 1999; Hattie & Yates, 2013; Tomic, 1993). As such, constructivism proposes that learners should be self-motivated in constructing knowledge through personal discovery, reflection, hands-on exploration, and active participation (De Lisi, 2002; Piaget, 1920).

In a constructivist environment, the teacher acts as a guide by providing the students with authentic and relevant learning experiences (Jones & Brader-Araje, 2002). The teacher effectively monitors and evaluates the learner’s progress while providing support through demonstrations, worked examples, and resources that utilize visualization tools such as charts, pictures, and animations (Brooks & Brooks, 1999; Vygotsky et al., 2002). This instructional strategy, or scaffolding, is an essential element of effective teaching in constructivism bridging the gaps in what a learner knows (prior knowledge) and what they are expected to know at a given point in their learning (Rosenshine & Meister, 1992; Vygotsky, 1986; Wood et al., 1976). Scaffolding is beneficial as it is purposefully designed to guide learners toward greater independence in their acquisition of new knowledge (Sawyer, 2014) and can be gradually removed as learners achieve this increased independence in the learning process (van de Pol et al., 2010).

The constructivist learning environment is marked by engagement, participation, and the social and cultural influences which contribute to the learner’s ability to create personal meaning of new information (Phillips & Early, 2000). While the incorporation of experiential or “hands-on” learning is highly valued (Jones & Brader-Araje, 2002),
constructivism has been criticized for overemphasizing the role of the learner and providing minimal guided instruction (Kirschner et al., 2006; Miles, 1997). In this type of environment, learners can become frustrated with both the perceived lack of instruction as well as slow progress due to their lack of prerequisite skills (Brown & Campione, 1994; Tuovinen & Sweller, 1999).

Because of the perceived frustration, traditional methods of instruction often fall short for constructivists. Multimedia instruction can fill the gap and provide the learner with the tools to create meaning from their experiences (Bransford et al., 2000). Instructional material that allows the learner to complete tasks in real-world situations, use social platforms to collaborate and debate ideas, control their progress, participate in reflective practices, use simulations to recreate and test processes, have information presented in a variety of ways, and having assessments that focus on the transfer of knowledge and skills rather than memorization of facts (Gregerson et al., 2013; Krogh, 2010; Mayer & Moreno, 2002a). Using multimedia instruction as it applies to constructivism moves the focus from teacher to learner in a collaborative and supportive environment (Gupta, 2011; Olusegun, 2015).

A new idea challenging the limitations of constructivism, as well as that of behaviorism and cognitivism, connectivism suggests that knowledge is created beyond the level of the individual and is constantly shifting and changing (Siemens, 2005). This paradigm shift expands active engagement and socialization to a network or digital space where the learner can discern and interpret information within a community of worldwide learners (Siemens, 2007).
Connectivism

Connectivism, seemingly developed for the technological environment of the 21st century, emphasizes the acquisition of new knowledge as a fluid process occurring within online communities and digital learning spaces (Siemens, 2005). Connectivism is based on a network of worldwide learners’ active participation and socialization promoting learner engagement beyond the typical classroom (Siemens, 2007). Learners use technology to form information networks and learning communities that participate in the creation of new knowledge rather than just consuming it (Dunaway, 2011). In an online environment, the individual contributes to the content, dispersing information into the network where it is accessed by other learners who, in turn, alter and adjust the information (Duke et al., 2010). As such, the creation of new knowledge rests on the diversity of opinions (Siemens, 2005). In this learning environment, the ability to learn and access information is more important than what is currently known (Siemens, 2005). The ability to filter and process what is valuable and important to the learner is essential for successful learning (Tschofen & Mackness, 2012), and the ability to see connections between ideas and concepts is a necessary skill (Siemens, 2005).

In a connectivist’s environment, the teacher’s role is redefined from an authority figure or guide to that of a curator, facilitator, and administrator of the “networked” learning space (Siemens, 2005). These new roles blend the teacher’s expertise with the learners’ need to create knowledge by directing them to resources and learning opportunities (curator), encouraging them to critically evaluate sources (facilitator), and creating spaces where the knowledge can be shared, explored, and connected (administrator) (Spector et al., 2010). With the guidance of the teacher, learners develop
critical thinking skills, foster problem-solving abilities, and discriminate between important and unimportant information (Duke et al., 2010).

While user-generated content can provide learners with multiple views on a subject, it is also of concern to critics who question the skill level of the content contributors (Haber et al., 2013; Ulrich & Nedelcu, 2015; Wildavsky, 2015). Concern has also been expressed as to whether the dedication of these contributors to making the content relevant and accurate is sustainable (Clarà & Barberà, 2014; Şahin, 2012; Sobrino, 2011). Some educators argue that connectivism is lacking in pedagogy based primarily on a perceived lack of rigor (i.e., lack of lesson objectives, assessments, critical activities, and assignments) and they question the accuracy of subject matter citing that it is often unvetted by experts in the field (Stacey, 2013; Ulrich & Nedelcu, 2015; Bell, 2011). Others express concerns that connectivism does not address issues such as the lack of direct human interaction in an online environment, language or cultural barriers, and intellectual property (Bransford et al., 2000; Olcott Jr, 2012; Reese, 2015). In addition, connectivists assume that individuals who participate in open online learning environments are active, self-directed participants. For connectivist’s assumptions to be true, a learner should possess a strong motivation to learn, be organized, self-disciplined, comfortable with independent work, and view problems as challenges to be mastered (du Toit-Brits & van Zyl, 2017). However, critics observe that not all individuals possess the abilities or characteristics necessary to set personal goals (Chaplot et al., 2015; Hew & Cheung, 2014). Along with these criticisms, it is broadly debated whether connectivism is a learning theory, an instructional theory, or a pedagogical view, with arguments made
to support each outlook. Nonetheless, it is a decidedly new approach to the way we learn (Duke et al., 2010).

**Summary of Learning Theories**

The discussion of the four theories (behaviorism, cognitivism, constructivism, and connectivism) and their methods of implementation illustrates and supports the research that suggests there is no single approach to learning that is more effective or efficient than another. The learning that takes place using any of these theories is dependent on many factors including the level and experience of the learner, the type of content being learned, and the load it places on the learner’s memory structure. Working knowledge of these theories allows for flexibility in the design of multimedia instructional material to accommodate both the learner and the content.

**Instructional Strategies and Methods in the Era of Digital Multimedia**

Instructional strategies guide and enable a learner’s processing and mastering of content (Dick et al., 2015) and help the instructor to achieve learning objectives (Gorsky, 2008). Instructional strategies are performance-based and grounded in learning theories, accountability, and outcomes assessments (Dick et al., 2015; Gagné & Gagné, 1985). Student-centered instructional strategies need to vary depending not only on the context and resources available, but also on the needs of the students (Branch, 2009).

Instructional strategies employ various instructional methods to create learning environments, share information, and engage students (Weston & Cranton, 1986). An instructional method is a set of learning outcome-oriented activities for learners to perform (Neumann & Koper, 2010). Examples of instructional methods include lectures, class discussions, group projects, self-paced lessons, independent studies, journals, and
simulations (“Instructional Strategies,” 2002; Weston & Cranton, 1986). The appropriate methods selected for instruction should be flexible and based on the learning objectives, student needs, abilities, and strengths, as well as the types of resources available to teachers and learners (Branch, 2009; Robertson & Lang, 1991).

Educational technologies are the hardware and software used to achieve learning objectives and engage learners (Ely, 1995; Muffoletto, 1994; Roblyer, 2003). Technology was first used in instruction to supplement and improve learner skills through practice exercises, explanation of difficult concepts, providing problem-solving experiences, and assessing learner progress (Reiser, 2001). Using technology to augment instruction was beneficial to learners requiring additional practice to supplement that which the teacher could not provide due to the time constraints of in-class instruction (Schunk, 2008). While the use of technology in instruction has the potential to improve learner success, the level of success depends on how the technology is incorporated into instruction (Archer, 1998; Clark & Mayer, 2008).

Adoption of educational technology in the 20th century used a technology-centered design approach that generally failed in contributing to lasting improvements in education (Cuban, 1986; Mayer, 2014a). Learners were forced to adapt to the technology instead of the technology adapting to the cognitive needs of the learner (Mayer, 2014a). In contrast, a learner-centered approach seeks technology that is designed to meet the cognitive needs of individuals (R. E. Mayer, 2014a).

Digital multimedia that use guiding principles in learner-centered instruction has the potential to foster meaningful learning rather than rote learning (Mayer, 2014a). The ever-increasing rich set of multimedia resources, which better adapt to the needs of
learners, can help instructional methods to be carried out more effectively, and in turn, better support instructional strategies.

**Teacher-Centered Instruction**

Traditionally, education has been teacher-centered. In teacher-centered instruction, the teacher sets learning expectations, engages and keeps the attention of the students, and evaluates student progress (Allendoerfer et al., 2014; Dean & Kuhn, 2007; Rosenshine, 1986; Wittrock, 1986). The teacher guides the learners in an orderly and well-disciplined environment by employing a variety of teaching strategies (i.e., lectures, teacher-led demonstrations, and teacher-guided class discussions) and providing feedback as the learner masters a subject (Chall, 2000; Livecchi et al., 2004; Pierce & Kalkman, 2003). The teacher selects the topics, provides the information, assigns the activities, and controls the classroom environment (Ahmed, 2013; Dowaliby & Schumer, 1973; Minter, 2011; Rosenshine, 2008). Teacher-centered instruction aligns with the theory of behaviorism that suggests a student learns because the teacher knows how to plan the goals and presents the material via lesson plans containing the method, organization, and sequence of material (Hattie & Yates, 2013; Schunk, 2008; Paris, 2016). Learners are expected to progress through the content at the pace that a teacher recommends; their engagement and the evidence of their success is demonstrated by the improved quality of work through successive assignments (Harrington & Zakrajsek, 2017; Tomic, 1993).

Learners in a teacher-centered classroom traditionally take a more passive role (Chall, 2000; Garrett, 2008; Livecchi et al., 2004). Learners are told what is expected of them; they take notes, complete assignments, respond to questions, and are assessed through objective or standardized tests (Peters, 2013). Teacher-centered instruction has
been practiced for many decades. Educational professionals, however, have debated the relevance and effectiveness of this direct instruction and challenged this regimented process asserting that it ignores the mental processes involved in more complex or higher levels of thinking, learning, and application (Cohen, 2002; Livecchi et al., 2004; Peters, 2013; Thorndike, 1920; Zimmerman & Schunk, 2003). There is limited empirical evidence supporting that rote learning, drilling, and testing result in mastery of the subject, long-term retention of subject matter (Brown, 2003; Minter, 2011; Pierce & Kalkman, 2003), or application of skills in other contexts (Cohen & Scheer, 2003; Livecchi et al., 2004; Peters, 2013; Thorndike, 1912). In response to these criticisms, efforts have been made to shift away from exclusively teacher-centered delivery of knowledge to the creation of a learning partnership between teachers and students (Goodlad, 1984; Hirsch, 1999; Jensen, 2008; Kong, 2012; Palmer et al., 2001).

Early research postulated that technology in the classroom would help develop skills through drill and practice, tutoring exercises, or remedial instruction (Bialo & Sivin, 1990; Gibson, 2001; Ingram, 1994). The teacher continues in the primary role intervening when a learner continues to have difficulty with the exercises, while the learner controls the pace and difficulty level. The teacher individualizes instruction and enhances the learning experience using instructional resources (Ingram, 1994; Means, 2005; Noeth & Volkov, 2004). The primary goal of technology in a teacher-centered classroom is to improve the effectiveness of the teacher and support their role as a primary figure in the learning process (Gibson, 2001; Means, 2005). Digital multimedia allows teachers to supplement the verbal modes of instruction with audiovisual
instructional material thereby taking advantage of the way learners process information (Mayer & Sims, 1994).

**Learner-Centered Instruction**

The paradigm shift from teacher-centered instruction to one centered on the learner had its origins in the cognitive theories that placed more emphasis on the complexities involved in learning and how information is processed (Dewey, 1998; Montessori, 1964; Piaget, 1974; Vygotsky, 1978). In learner-centered pedagogical instruction, the focus is redirected to individual learners - their experiences and prior knowledge, perspectives, backgrounds, and learning needs (Bransford et al., 1999; Hattie & Yates, 2013; McCombs & Whisler, 1997; Norman & Spohrer, 1996; Overby, 2011). As active participants, learners seek knowledge through self-initiated research, provide reflection about the process, and connect it to their other areas of interest (Norman & Spohrer, 1996; Watson & Reigeluth, 2008). The teacher shares control of learning through focused guidance (e.g., encouraging collaboration, discussion, and reflection on topics; asking pointed questions; and offering purposeful feedback) (Sharkey & Weimer, 2003) while supporting learners as they create connections between prior knowledge and new knowledge (Bidokht & Assareh, 2011; Costa & Kallick, 2004; Grow, 1991). The learning process becomes more active; teachers challenge individual learners to advance beyond their comfort zones (Brown, 2008; Wright, 2011; Ambrose, 2010; Bransford et al., 2000).

Three potential areas of concern have surfaced with the shift in control from teacher to learner: 1) student readiness for a learner-centered classroom, 2) mastery levels of a discipline and the effects on student choices, and 3) classroom management issues.
The first concern is that not all learners are prepared to take a more active role in their learning; the lack of motivation, self-discipline, and the added responsibility of setting goals may result in anxiety, potentially impeding the full participation and exchange of ideas among all class participants (Abbasi & Hadadi, 2014). The second concern centers on being able to successfully balance the emphasis on learner needs and choices with the discipline’s knowledge structure and levels of mastery that determine success in the subject area (McKenna, 2013). Teachers need to develop strategies that articulate a clear set of objectives while maintaining a high set of standards for the discipline; learners can thereby make informed decisions in selecting and discussing topics of relevance (Froyd & Simpson, 2008; Massouleh & Jooneghani, 2012). Critics have cited classroom management as a third source of concern, in particular, factors that can both disrupt and enrich the learning environment (Froyd & Simpson, 2008; Massouleh & Jooneghani, 2012). Teachers need to be cognizant of the classroom dynamics that can play a role in the success or failure of learner-centered education including high competitiveness (causing a focus on grades and not learning) (Heffernan et al., 2010) as well as learners expecting the traditional roles of hierarchy in the classroom (learners may not be ready to assume shared control of the learning process) (Smithee et al., 2016). Consideration of these areas of concern when implementing a learner-centered classroom can be a challenge for teachers, but when successfully addressed becomes a method of promoting academic curiosity, responsibility, and active learning (Filatova, 2015).

Learner-centered education requires the flexibility of both students and teachers with the technology providing the tools to support and enhance the learner-centered environment. Through practice, drill opportunities, and testing for knowledge retention,
learners are given the opportunity to engage with interactive, and independent thinking learning opportunities (Mayer, 2003; Mayer & Moreno, 1998; Moreno & Mayer, 2000). Learning can be monitored providing instructors with data about the individual’s progress and thus can be adapted as needed (Bonk & King, 2012).

During problem-solving tasks, inquiry-based coursework, and project-based assignments, learners can benefit from the inclusion of multimedia (Mayer, 2003; Moreno & Mayer, 2000). For example, learners on a problem-solving task rely on visual and verbal cues provided through images and videos, and their attention is engaged when processing the steps needed to complete problem-solving tasks (Brush & Saye, 2008; Hoffmann & Ritchie, 1997; Neo & Neo, 2001). Learners who are engaged in inquiry-based or project-based learning can be in touch with information, examples, and ways to collaborate with individuals outside their physical boundaries (Mayer, 1999, 2017). Multimedia tools and lessons allow learners to explore and immerse themselves in unique situations and places that would be impossible using textbook-only instruction (Mayer, 2008; Mayer & Anderson, 1992; Mayer & Moreno, 2002b; Moreno & Mayer, 2000). Using digital multimedia in these learner-centered activities allows for individualization of study, self-paced lessons, and on-time feedback that fosters learner growth (Mayer, 2003; Moreno & Mayer, 2000). Careful planning and the analysis of curriculum and pedagogy, educational technology, and digital multimedia resources can offer a balance of instructional methods that will transform learning, support creativity, collaboration, and critical thinking, all hallmarks of learner-centered instruction (Bonk & King, 2012; Gibson, 2001; Noeth & Volkov, 2004).
Summary of Instructional Approaches

While both teacher-centered and learner-centered instruction have their advantages and disadvantages and vary in how the technology is employed in the classroom, current research proposes that teaching should be neither teacher-centered nor learner-centered but a combination of both bonded together by the goal of guiding and involving students in their learning (Palmer, 2007). Students who are guided and supported in their learning benefit from the flexibility afforded by the use of self-paced digital multimedia resources. These resources also provide individuals with more control over their learning. The instructional methods should be chosen based on sound pedagogy. Likewise, multimedia resources should be designed, developed, and used based on the guiding principles of multimedia and the research on how learners assimilate new information as described in the following sections.

Human Memory

A partnership between education and psychology has provided educators with a means of describing, understanding, and measuring the learning process (Zimmerman & Schunk, 2003). Studies in cognitive psychology apply to a broad range of higher mental processes including memory, attention, perception, problem-solving, and mental imagery (Bruning et al., 2004). Understanding human memory is critical to understanding the learning process. The ability to respond to stimuli, hold and store information in an organized manner, and retrieve that information in response to relevant new stimuli is the focus of research in the cognitive sciences (Baddeley & Hitch, 1974). For effective, efficient, and hypothetically long-lasting learning, educators need to consider the cognitive processes of learners (Greeno et al., 1996; Khalil & Elkhider, 2016).
Memory Structure

While educators and cognitive scientists do not agree as to how individuals assimilate, code, and retain information, including which processes are important or how they occur (Matlin, 2013), most agree that there are three types of memory: sensory memory, working memory, and long-term memory (Baddeley, 1999; Kahana, 2012). Information processing begins when input is received through the senses (sensory memory), is moved to temporary storage where it is managed (working memory), and is finally integrated and moved to long-term storage where it can be retained and later retrieved (long-term memory) (Atkinson & Shiffrin, 1968).

Sensory Memory. Sensory memory is the term used to describe the fleeting perception of information received by the senses that typically lasts for just a few seconds (Cowan, 1998; Lieberman, 2012; Sperling, 1963). Input from the senses is perceived only long enough in sensory memory to be processed and then transferred to working memory (Baddeley, 2007; Craik & Lockhart, 1972). The degradation of information in sensory memory varies in length of time for the different sensory stimuli. For example, iconic memory holds a visual image for less than a second, echoic memory retains sounds for approximately one to two seconds, while haptic or tactile memory is retained the longest at three to four seconds (Atkinson & Shiffrin, 1968; Broadbent, 1958; Miller, 1956; Pasternak & Greenlee, 2005; Sperling & Hill, 1960). Stimuli detected by the senses can be either ignored and disappear from sensory memory or can be attended to and thus transferred to working memory for further processing (Baddeley, 2010a; Introduction to Psychology, 2015; Winkler & Cowan, 2005)
**Working Memory.** Working memory processes information transferred from sensory memory and is necessary for complex tasks such as language comprehension, learning, and reasoning (Baddeley & Hitch, 1974). The original working memory model by Baddeley and Hitch (1974) was composed of the central executive and two, dependent subsystems: the phonological loop and the visual-spatial sketchpad. The central executive controls the information to and from the dependent systems; the phonological loop holds verbal content that is heard and manages the articulatory process that allows text to be rehearsed through repetition; the visual-spatial sketchpad stores information on how images appear and allows for the manipulation of those images. An extended model (Baddeley, 2000) includes the episodic buffer to explain, in part, how visual and verbal information are integrated. Figure 1 shows both the original and extended models.

**Figure 1**

*Working memory models: (a) original model (Baddeley & Hitch, 1974) and (b) extended model (Baddeley, 2000)*

Researchers agree that working memory has a limited capacity, however, opinions differ as to the amount of information that can be processed at any given time. Early
research proposed seven chunks or groups of information (plus or minus two) as the limit of working memory (G. A. Miller, 1956), while subsequent research determined that the limits were closer to four chunks of information (Cowan, 2001; Oberauer et al., 2016). Exact numbers continue to be disputed as more research demonstrates that capacity is dependent on a variety of factors including focus of attention, demands placed on working memory from cognitive load, an individual’s developmental stage, and the level of expertise involved (Baddeley, 2003; Cowan, 1998; Cowan & Morey, 2006; Oberauer et al., 2016; Unsworth & Engle, 2007; Unsworth et al., 2014). While the capacity debate continues, it is agreed that new information is organized and elaborated upon in the working memory and subsequently integrated and stored in long-term memory (Baddeley, 2007; Cowan, 1998; Craik, 2014; Huk & Ludwigs, 2009).

**Long-Term Memory.** Long-term memory is the component of the memory model where information enters from working memory and is retained for an extended period of time (Atkinson & Shiffrin, 1968; Baddeley & Hitch, 1974; Bruning et al., 2004; Cowan, 2009). Theoretically, long-term memory is unlimited, permanent, and can be activated with proper cueing (Abakumova et al., 2016; Aben et al., 2012; Ainley, 2006; Cowan, 2008; Craik & Lockhart, 1972). Long-term memory is divided into two main types: explicit (i.e., conscious memories or those we are aware of) and implicit (i.e., unconscious memories or those that are used without awareness) (Goldstein, 2015). Explicit memory is associated with facts and knowledge of individuals’ surroundings (e.g., recalling dates, remembering names, reading a music score) (Sternberg & Sternberg, 2011). Implicit memory is used to complete or perform tasks without conscious awareness (e.g., walking, riding a bike, typing) (Sternberg & Sternberg, 2011).
While long-term memory is thought of as having a limitless capacity, cognitive research has provided evidence that stored knowledge can be susceptible to faulty recall or accessibility due to a variety of factors including lack of focus, errors in making connections during the encoding process, injury, aging, and disease (Bahrick et al., 1975; Cunningham et al., 2015; Kane & Engle, 2000; Unsworth, 2016; Unsworth et al., 2012). Being able to connect new information with previously stored information is critical in the ability to process, retain, and retrieve information efficiently and effectively from long-term memory (Baddeley, 1999; Baddeley & Hitch, 1974). Through purposeful connections (relevancy), elaboration and rehearsal (processing or thinking about the meaning), and distributed practice (reviewing information over multiple sessions), information can be successfully moved into long-term memory for later retrieval (Sprenger, 1999; Sweller, 2016; Unsworth et al., 2012).

**Cognitive Load**

The amount of working memory resources being used when processing information is referred to as cognitive load (Sweller, 1994). There are three sources of cognitive load: intrinsic, extraneous, and germane. Intrinsic load describes the complexity of information associated with a subject (e.g., a simple addition problem versus a complex algebraic equation) and the amount of effort that is needed to learn the material (Sweller, 1988). This type of load is difficult to reduce or alter due to the innate complexity of the subject but can be helped by ensuring learners first master the fundamental principles before moving to more complex tasks (Bannert, 2002; Brunyé et al., 2008; Martin, 2014; Paas et al., 2004). Working memory capacity can also be strained by extraneous cognitive load (Chandler & Sweller, 2016). Extraneous load refers to the
load on working memory that is created through the manner in which information is presented (e.g., distracting information) that makes a task more complex creating less than optimal conditions for processing new knowledge (et al., 2011a). It is thus recommended to reduce the extraneous load by avoiding distractions for the learner, eliminating unnecessary tasks during the learning process, and presenting the material in an easy-to-access and understandable manner (Bannert, 2002; Brunyé et al., 2008; Martin, 2014; Paas et al., 2004). Germaine load is devoted to acquiring and automating schemata in long-term memory (Ayres & Paas, 2012; Chandler & Sweller, 2016; de Jong, 2010). Germaine load should be optimized for effective learning. Using learning aids, such as mnemonics, practice exercises, and segmenting content into manageable learner-controlled lessons can help individuals comprehend and retain information (Bannert, 2002; Brunyé et al., 2008; Martin, 2014; Paas et al., 2004). Together, intrinsic, extraneous, and germaine loads contribute to the overall cognitive load imposed on learners (Paas et al., 2004; Paas & van Gog, 2006).

**Cognitive Load Theory.** Cognitive load theory (CLT) was developed to understand how the cognitive load produced by solving problems using a “means-end” strategy as opposed to goal-free or worked example problems could impede a learner’s ability to process new information (Sweller, 1988). As the working memory processes information from external sources, it determines the relevance of the stimuli, draws connections to previous experiences, and reflects on new knowledge in order to apply it to new situations (Sweller, 1994; Sweller et al., 2011b). However, empirical research has suggested that working memory can only process a finite number of elements simultaneously (Sweller, 1994; van Merriënboer & Sweller, 2005). When a learner is
asked to process information that exceeds their working memory capacity, the resulting cognitive overload results in little to no learning (Sweller, 1988).

Various factors have potential effects on cognitive load, including distractions from technological and personal sources (Charlesworth, 2008; De Vita, 2010; Joy & Dunn, 2008; Song & Oh, 2011; Wehrwein, & DiCarlo, 2007). CLT research addresses these influences on learning and proposes suggestions that can facilitate learning. Utilizing strategies such as building on a student’s prior knowledge, segmenting content into smaller chunks, eliminating irrelevant material to reduce redundancy, and using both auditory, verbal, and visual instructional material to present information helps manage working memory thus aiding in the acquisition and retention of knowledge (Anderson, 1996; Chandler & Sweller, 2016; Clark & Harrelson, 2002; Sweller & Chandler, 1994; Van Merriënboer & Sweller, 2005).

Learning with Multimedia Technology

Multimedia resources have been developed with guiding principles focusing on how individuals best learn when utilizing multimedia instructional resources (Mayer, 2005, 2014a) and have been adopted in the classroom to improve teaching and learning (Reiser, 2001). Research on using digital multimedia can help teachers make rigorous evaluations as to the benefits for their learners. The principles are outlined in the next several subsections.

The Cognitive Theory of Multimedia Learning

The cognitive theory of multimedia learning (CTML) focuses on the use of multimedia as an aid to learning; specifically, CTML suggests that individuals learn more efficiently when instructional content uses both words and pictures (Mayer, 2014c).
CTML is based on three assumptions: First, there are two separate channels in working memory for processing auditory and visual information. Second, each of these channels has a limited capacity. Third, learners actively process information (i.e., select, filter, organize, and integrate) for learning (Mayer, 2014a). Learners process the incoming information forming mental models to integrate the new knowledge with prior knowledge facilitating the move into long-term memory, allowing the learner to progress from novice to expert learner (Mayer, 2014c).

CTML asserts that, for meaningful learning to occur, certain cognitive processes must be engaged: the learner focuses on relevant words and pictures (selection) (Mayer, 2010), the words and pictures are organized into coherent representations of words and pictures (organization), and the learner integrates word-based and picture-based representations with prior knowledge. These cognitive processes and the corresponding research attempt to explain how the learner selects, organizes, interprets, and stores information from words and pictures demonstrating the multiple paths that incoming stimuli can take in the cognitive process (Mayer, 2014c). While these processes are monitored and coordinated by the learner, they do not have to follow a linear path as illustrated in Figure 2.
The Principles of Multimedia Learning. The principles of multimedia learning provide guidelines for evidence-based design of instructional resources that incorporates words and pictures (Bannert, 2002; Brunyé et al., 2008; Martin, 2014; Paas et al., 2004). The effectiveness of the use of multimedia to improve learning is thought to be dependent on what is considered meaningful learning. Cognitive research distinguishes between rote memory and deeper understanding when defining learning (Butcher, 2014; Mayer & Pilegard, 2014). To consider the impact of multimedia on learning outcomes, research on the principles of multimedia learning focused on tests of memory and tests of deeper understanding to measure effectiveness and the impact on the cognitive load of learners across various types of multimedia (Butcher, 2014).

The following sections focus on four principles of multimedia learning that have been frequently investigated, are grounded in cognitive theory, and have been used extensively in practice: the multimedia principle, split-attention principle, redundancy principle, and segmenting principle.

The Multimedia Principle. The multimedia principle states that learning with words and pictures is more effective than with words alone (Butcher, 2014; Mayer, 2009)
and asserts that words and pictures received through auditory and visual pathways evoke different cognitive processes; the resulting mental representations aid comprehension and retention of information (Butcher, 2014; Fletcher & Tobias, 2005; Mayer, 2009). While the principle uses the umbrella term of *pictures*, this term includes varied forms of visual content including illustrations, graphs, charts, photos, diagrams, animations, and videos. Figure 3 provides an example of the multimedia principle.

**Figure 3**

*Multimedia material explaining the process of lightning (Mayer et al., 1996)*

Research on the multimedia principle proposes conditions and situations in which learners benefit from multimedia resources. In certain disciplines, learners may require help in how to use pictures effectively often failing to generate visual representations during learning (Cromley et al., 2010). Scaffolding may also be necessary for individuals who need help in distinguishing between merely being able to access and view multimedia resources and deeper learning from the multimedia content (Cromley et al., 2010). It is suggested that further research is needed to study how interaction with multimedia affects cognitive processing and learning outcomes across a variety of
disciplines with a more varied group of learners. This will help fully define all the boundary conditions for the multimedia principle (Butcher, 2014).

Empirical data has shown that the effectiveness of the multimedia principle is also dependent on the experience level of the learner (Butcher, 2014; Clark & Mayer, 2012; Fletcher & Tobias, 2005). It confirms the effectiveness of the design for novices while demonstrating that as levels of learner knowledge in a discipline increase, the relative effectiveness of the multimedia instructional format decreases (Kalyuga, 2012, 2014). Multimedia resources can help provide complex learner-centered instruction; conducting relevant studies can provide data on how the multimedia principle applies in those situations.

When considering the multimedia principle boundaries for novice learners, visual representations should be simplified into essential components with the text integrated with the visual content (Chandler & Sweller, 1992; Mayer, 1989). Animations should be used when motion is a critical component of the content and learners are not able to mentally animate the materials (Höffler & Leutner, 2007). Visual cues, such as highlighting, are beneficial in directing attention to relevant information facilitating the processing of new knowledge (de Koning et al., 2010). Research has also demonstrated that designing instructional multimedia that can improve learning outcomes is dependent on the content to be learned coupled with the characteristics of the learners (Butcher, 2014; Isa et al., 2011).

**The Split-Attention Principle.**

The split-attention principle states that learning is more effective when multiple, mutually dependent sources of information essential for understanding the material are
presented in close proximity both physically and temporally (Ayres & Sweller, 2014). When an individual needs to integrate information from physically or temporally distant sources it may increase extraneous cognitive load and have a negative effect on the learning process (Ayres & Sweller, 2014). The principle is illustrated in Figure 4(a) where an individual is required to first read the statement and then examine the information provided by the diagram. By integrating the statement with the diagram as illustrated in Figure 4(b), the individual does not need to search two sources of information, thereby reducing the working memory load (Ayres & Sweller, 2014).

**Figure 4**

*Split attention principle: (a) attention split between text location and diagram and (b) integrated format of text and diagram p. 208. (Ayres & Sweller, 2014)*

![Diagram](image)

Split-attention has been illustrated in a variety of discipline areas including geometry (Chandler et al., 1990; Tarmizi & Sweller, 1988), physics (Ward & Sweller, 1990), accountancy (Rose & Wolfe, 2000), music (Owens & Sweller, 2008), physical
therapy (Pociask & Morrison, 2008), and medicine (Cierniak et al., 2009). As an example, two groups of learners were asked to complete complex problem-solving tasks with one group using material that was in an integrated format while the other group had a split-attention format. The integrated format proved superior (Ayres & Sweller, 2014; Ward & Sweller, 1990) with results suggesting that learners using integrated information required less time to study the information and scored higher on subsequent tests (Chandler et al., 1990).

There are several ways of helping learners mitigate split-attention. Directing the individual’s attention through the use of color coding to highlight relevant information (Kalyuga et al., 1999), dividing explanatory text into smaller segments (Kalyuga et al., 1999), and the use of hyperlinks to give the learner more control over the content (Bétrancourt & Bisseret, 1998).

There are certain conditions or boundaries where the split-attention principle does not apply. Learner characteristics such as the level of expertise play an important role in the effects of split-attention. A more expert learner can find the same amount of material deleterious, distracting, and redundant thus interfering with the learning process (Kalyuga et al., 2003; Sweller et al., 2011a, 1998). The split-attention principle also does not apply in instructional material where the information requires low element integration (Chandler & Sweller, 1992; Kalyuga et al., 1999; Sweller & Chandler, 1994) or presents redundant information (Chandler & Sweller, 1992; Sweller & Chandler, 1994). Considerable multimedia resources require learners to split their attention. However, the split-attention principle provides guidelines to improve learning with multimedia resources, based in theory and empirical evidence (Ayres & Sweller, 2014).
**The Redundancy Principle.** The redundancy principle suggests that when the same content is presented in multiple forms or contains unnecessary elaborations, it interferes with, rather than facilitates, learning (Kalyuga & Sweller, 2014). As the learner tries to coordinate redundant information with essential information, it increases the load on working memory thereby wasting limited cognitive resources on unrelated learning activities (Kalyuga & Sweller, 2014). There are two variations of the redundancy principle: The first occurs when identical information is presented in two or more forms simultaneously (e.g., words that are also described in both auditory and written form) and when the information is repeated with unnecessary elaborations (Kalyuga & Sweller, 2014). Figure 5 (a) demonstrates the redundancy principle of having the words and narration duplicated in the instruction, example (b) illustrates the information with unnecessary elaboration, and (c) is the redesign showing the key talking points of the narration.

**Figure 5**

*Redundancy principle: (a) identical narration and written text, (b) unnecessary elaboration, and (c) content contains talking points of narration in this example from a web writing class. (Tkacs, 2015)*

![Figure 5](image-url)
The redundancy principle was first experimentally demonstrated as early as 1937 when one group of learners was shown a picture with the corresponding descriptive words provided both in print and audibly. The second group had the same conditions except for the picture. Test performance was higher for the group without the picture (Miller, 1937). Subsequent studies related to the redundancy principle described results supporting the original supposition that if the main idea is understandable to begin with, coordinating it with additional details has no function (see Carroll et al, 1987; Reder & Anderson, 1982; Torcasio & Sweller, 2010). Additional studies describing phenomena related to the redundancy principle found that asking individuals to verbalize a picture could prevent its subsequent recognition (Schooler & Engstler-Schooler, 1990); solving math problems is more difficult if additional information was included with the problems (Lesh et al., 1987); learners who studied a diagram without text had better comprehension then those who were provided with a diagram and text (Holliday, 1976).

The redundancy principle is more relevant to experts because as levels of expertise increase, redundant explanations become increasingly unnecessary and ineffective (Kalyuga, 2007). While eliminating redundant content from a multimedia lesson will be of particular benefit to the expert learner, it has not conclusively indicated how much material may be redundant to each learner (Kalyuga et al., 1999). Those individuals with more experience may take longer to process the extraneous material requiring more cognitive resources and thus interfering with, rather than facilitating, learning (Kalyuga, 2013; Kalyuga & Sweller, 2014). Being mindful of the boundary conditions of the redundancy principle and the cognitive load placed on individuals as they are learning (Sweller et al., 2011a), it is recommended that it should be first
determined whether the information is intelligible on its own or needs more explanatory material and, if possible, presented in a single form (Kalyuga & Sweller, 2014). Redundancy under one set of circumstances can be vital under another; information that is redundant for one individual may be essential to another (Kalyuga & Sweller, 2014). It is also noted that redundant content is not only words and pictures but includes other sources such as background music, graphs, annotations, stories, non-essential words, and additional details. When using multimedia resources, the cognitive load theory can provide guidance on what conditions determine redundancy (Kalyuga, 2009; Kalyuga & Sweller, 2014; Sweller et al., 2011a).

**The Segmenting Principle.** The segmenting principle states that individuals learn better when a multimedia message is presented in learner-paced segments rather than as a continuous unit (Mayer & Fiorella, 2014). This principle suggests that a learner, viewing a continuous multimedia lesson, may not have enough time to effectively process the information if it is presented at too fast a pace thus resulting in cognitive overload (Clark & Mayer, 2010; Mayer, 2012; Mayer et al., 2001; Mayer & Pilegard, 2014). The segmenting principle further indicates that breaking a lesson into smaller segments, which allows for self-pacing, is beneficial to novice learners when the information is complex, fast-paced, and requires detailed explanations through the use of pictures and words (Mayer, 2012). When new information is presented at a rapid pace, the learner can experience cognitive overload and thus understanding of the information may not be achieved (Mayer, 2009; Mayer & Moreno, 2003). In order to ease cognitive load, allowing time between successive short segments is beneficial to the learner (Mayer & Pilegard, 2014). Allowing the individuals to control the pace of the presentation gives the
learner time to carry out the required cognitive processing (Mayer, 2012). An example of a self-paced lesson with learner controls is illustrated in Figure 6.

**Figure 6**

*Example of a segmented self-paced chemistry multimedia lesson. Learners advance or move backward at their own pace, using the left or right arrows (Sattsangi, Tkacs & Byers, 2010)*

The use of segmented learning resources has shown positive outcomes when facilitating self-paced learning for novice learners. When tested across a range of disciplines, learners using self-paced segmented lessons performed better than control groups in knowledge transfer tests (Mayer & Chandler, 2001; Mayer et al., 2003) and recall tests (Hasler et al., 2007; Mayer & Pilegard, 2014). Segmented resources are more beneficial for learners with lower working memory capacities (Lusk et al., 2009) and for learners with limited prior knowledge (Ayres, 2006). For individuals with content expertise, as has been demonstrated with other multimedia principles, segmented learning resources could be distracting and perceived as a waste of their time, thus resulting in the expert reversal effect (Bransford, 2000; Hinds, 1999; Kalyuga, 2013; Rey & Buchwald, 2011).
While the literature provides empirical evidence of the benefits of the segmenting principle, more research has been recommended to determine the optimal segment size for the particular characteristics of the learner (Mayer & Pilegard, 2014). Additional studies would more clearly define the boundary conditions by determining 1) the relative effects of learner control of the pace and order of the presentation and 2) whether they are dependent on the characteristics of the learner or the characteristics of the task (Mayer & Pilegard, 2014).

**Summary of the Cognitive Theory of Multimedia Learning.**

A knowledge base for the CTML continues to grow with added empirical evidence supporting the related principles, including multimedia learning, split-attention, redundancy, and segmenting, as discussed in this section. Researchers have advocated that studies conducted on multimedia learning need to include practical learning situations in a variety of content areas, a broad range of learners, and an investigation of the effects of the multimedia principles on cognitive load (Clark & Mayer, 2008; Kalyuga, 2009; Mayer, 2009).

A review of the literature reveals common conclusions about multimedia learning in general. First, when the principles of multimedia design are implemented, multimedia instruction is well-suited to both the acquisition of new knowledge and the improvement of existing knowledge required in a discipline (Atkinson, 2005; Kozma & Russell, 2005; Lowe, 2005; Reinking, 2005; Wiley & Ash, 2005). Second, well-designed and implemented multimedia instructional resources are effective in aiding learners in forming new mental models (Atkinson, 2005; Kozma & Russell, 2005; Lowe, 2005; Reinking, 2005; Wiley & Ash, 2005). Third, conflicting results have been reported as to
the effectiveness of learners integrating word and picture-based representations with their prior knowledge (i.e., novices versus experts) (Atkinson, 2005; Kozma & Russell, 2005; Lowe, 2005; Reinking, 2005; Wiley & Ash, 2005).

Many studies examining the effectiveness of multimedia resources in learning have primarily focused on the subjects of reading, language arts, and STEM disciplines (Alexander, 1992; Alexander et al., 1994; Dochy, 1992; Perkins & Salomon, 1989). To make broader assumptions about the boundaries of multimedia resources, it would be beneficial to expand the research into less investigated disciplines, such as the arts (e.g., music, dance, painting, etc.). Few have investigated how learners in the arts respond when interacting with multimedia resources, or what advantages they may have when interacting with multimedia resources in other domains (Dacey, 2009; Graziano et al., 1999; S. Moreno, 2009; Owens & Sweller, 2008; Zatorre, 2005).

Music as a Unique Discipline in Multimedia Learning

Cognitive Advantages of Learning Music

The potential of music to improve the cognitive performance of learners was first demonstrated with evidence that listening to a Mozart Sonata improved preschoolers’ spatial reasoning performance (Rauscher et al., 1993). This study was later dubbed “the Mozart effect” after the expression used by a French researcher in his book Pourquoi Mozart? (Tomantis, 1991). Additional studies provide evidence that musical training (e.g., playing musical instruments) influences brain functions (Herholz & Zatorre, 2012; Pascual-Leone, 2001; Schlaug et al., 2005). During musical training, learners recall complex musical elements that include notation (system of written symbols representing musical sounds), tempo (speed at which a musical composition is played), and dynamics
(variations in loudness between notes or phrases in music) which are all part of a musical score (Randles & Pasiali, 2012). Music is a complex discipline that engages memory, recognition of patterns, and coordination of mental and physical abilities (Dalla Bella, 2016; Jäncke, 2009; Menon et al., 2007). Learners categorize and respond to the audio-visual stimuli by creating and accessing information in long-term memory thereby helping the learner develop a system of expectations, understandings, and meaningful patterns in their understanding of musical ideas (Cross et al., 2008). These cognitive functions are developed over time and are based on experience and repeated practice (Gruhn & Rauscher, 2011).

Music learning requires a regimen of repetition, error correction, and the use of feedback as one practices and refines their skills (Chi et al., 1982). The process of listening, singing, composing, and playing an instrument affects the motor, visual, auditory, spatial, and cognitive abilities due to brain plasticity (the ability of the brain to continuously change and adapt) (Hyde et al., 2009; Schlaug, 2015). Music learners routinely score higher on tests of mental rotation, visual attention, and line orientation (Rodrigues et al., 2013; Sluming et al., 2007; Stoesz et al., 2007) and show superior performance in memory recall, grammatical judgments, and pronunciation than non-music learners (Brandler & Rammsayer, 2003; Jakobson et al., 2008; Jentschke, 2016; Kilgour et al., 2000; Patston & Tippett, 2011; Stoesz et al., 2007). Those individuals who have studied music have demonstrated higher general intelligence than their non-musical peers in longitudinal studies involving memory, attention, and language; these skills continue to be of benefit even after individuals have discontinued their music learning (Gibson et al., 2009; Hille et al., 2011; Schellenberg, 2011).
In addition to the cognitive advantages, learning music also offers further advantages such as time management and organizational skills (Schellenberg, 2005; Pascual-Leone, 2001; Patel, 2010; Schlaug et al., 2005; Weinberger, 1998). Music learners, regardless of their level of expertise, routinely chunk musical elements into smaller units that are of a cognitively manageable size as they strive to perfect difficult passages, playing them over and over again (Chi et al., 1982; Ericsson et al., 1993, 2007). As a result of the cognitive activities in learning music, individuals can transfer or apply this knowledge or skill from one situation to another within the same domain or from one domain to another such as mathematics, science, and English (Gouzouasis et al., 2007; Guhn et al., 2019).

In recent studies, however, some researchers have disputed the cognitive benefits of learning music. For example, subsequent reviews of the Mozart effect indicate that the short-term effect is small concerning spatial abilities, and any nonmusical benefits can be explained by other characteristics and abilities of the individuals (Pietschnig et al., 2010). Other research has made the claim that the data pertaining to cognitive advantages of learning music cannot be reconciled to proven principles and findings in cognitive psychology (Schellenberg, 2003). Further, even with controls in place, it cannot be certain that those with musical training are identical on other dimensions such as socioeconomic status or IQ (Schellenberg, 2003). Additional data provides evidence that music learning has no impact on a learner’s non-music cognitive skills or academic performance (Sala & Gobet, 2020). While arguing that there is no significant evidence for improvement in domain-general cognitive skills or general intelligence, however, some studies noted that elements of music learning (focused practice, reading notation,
ear training, sight reading, and the use of feedback) have the potential to positively transfer to non-music disciplines with the intent to improve general skills (Lamont, 1998; Sala & Gobet, 2020; Schellenberg, 2003, 2016). Further research could provide more information on the way music learners process new information and whether those skills can be transferred to non-music disciplines.

Music learning can occur in various settings, including schools and private lessons (formal) or self-taught and community music groups (informal). Much research investigating the association between music learning and cognition has focused on formal music learning (Schellenberg, 2003). Formal music learning has structure, incorporates foundational music learning (e.g., music theory, music notation, exposure to musical styles), and depends on feedback and repetition of practice to enhance and strengthen skills. That is not to say that individuals that have informal music learning (i.e., have taught themselves to play an instrument or sing) cannot read music notation or do not practice on a regular basis, but they often lack skills that have been developed with guidance in a more formal setting (Bathgate et al., 2012). However, formal learning better facilitates translating musical symbols into complex motor operations, the coordination of independent movement of breath and hand control, and the memorizing and retrieval of intricate musical passages. Formal learning does all with attention to tone and rhythm that contribute to both structural changes and brain functions, which advance the learner from novice to expert (Schlaug, 2012) and possibly transfer these skills to other domains (Dalla Bella, 2016). However, limited research has investigated whether individuals with informal music learning have the same strength of skills and strategies
developed from their experience and the ability to apply them to learning in other disciplines.

**Technology and Multimedia Resources in Music**

As in many other disciplines, technology has become an integral part of the creation, production, expression, distribution, promotion, and enjoyment of music in all its forms (Hugill, 2010; Waddell & Williamon, 2019). For example, as learners try to refine their technical and musical skills, various technologies (e.g., the phonograph, digital instruments, phones, mp3 players, and computers) have become commonplace and nearly a requirement (Waddell & Williamon, 2019). Technology also provides resources that allow music learners to compose and perform their compositions on the computer (Verrico & Reese, 2016), unrestricted by the need for formal instruments. Furthermore, technology is invaluable in the design of instruments and the physics of sound (e.g., pitch, intensity, resonance, decibels, differences in sound waves and how they are produced by different instruments) (Hugill, 2010; Webster, 2012).

As music is an audio-visual art that depends on words and graphics (notation) to understand the discipline, multimedia resources can lend themselves to music learning. When used appropriately, multimedia resources indeed enhance knowledge and skills in music learning (Rudolph, 1996). Multimedia resources have been used to provide listening maps to musical scores (Pao et al., 2010), instrumental tutoring (Bauer, 2014), listening exercises (Baltzer, 1996), teaching vocal techniques (Wang, 2013), demonstrating basic elements of music literacy (Webster, 2017), and mastering the creative technique of improvisation (Fein, 2017). The use of multimedia resources in music learning further can provide flexibility, convenience, and the ability to offer
different learning situations to accommodate a variety of learners and abilities (Rechberger, 2017).

While existing literature provides evidence of the benefits of music learning on various aspects of individual development (e.g., cognitive functions, emotional development, life skills, etc.), there is still a lack of published literature regarding how individuals can transfer and apply the knowledge and skills acquired through music to learning in other disciplines. Further study would thus further contribute to the knowledge regarding the benefits of music learning and why this is impactful across other disciplines.

**Chapter Summary**

The current chapter provided a literature review on learning theories, instructional strategies, human memory, learning with multimedia, and music as a unique discipline in multimedia learning. This chapter started with a review of historical and current literature on learning theories (i.e., behaviorism, cognitivism, constructivism, and connectivism), their influence on instructional strategies, and their explanations of how individuals learn. Next followed a review of prevalent instructional strategies (both teacher-centered and learner-centered) that have the potential to provide the best learning experience for individuals. It then discussed research on human memory and the cognitive load that is placed on learners’ working memory as they assimilate new knowledge (Cognitive Load Theory). When addressing learning with multimedia, advances in technology were discussed as offering new ways of engaging the learner and transforming the learning process using multimedia instructional resources. Particularly, the cognitive theory of multimedia learning was explained along with its related principles (e.g., the multimedia
principle, the split-attention principle, the redundancy principle, and the segmenting principle), addressing when and for whom the use of multimedia in instruction is most effective. Finally, the unique domain of music that has not been a major subject of research in multimedia studies (e.g., STEM) was reviewed and included evidence of the distinctive cognitive characteristics of music learners and how these may relate to learning with multimedia. This literature review offers the foundations on which the current research study is built, subsequently discussed in Chapter 3.
Chapter III
Methodology

Overview

The purpose of the current study is to examine how music learning relates to learning with multimedia in non-music disciplines. The literature provides documented differences in information processing and management among music learners (Degé et al., 2011; S. Moreno, 2009; Tierney et al., 2013) as music learning involves diverse cognitive functions (Zatorre, 2005). This study hopes to provide information on how the music learning experience relates to segmented and non-segmented multimedia learning in non-music disciplines (Herholz & Zatorre, 2012).

The current chapter is organized in the following sequence: first, the research questions for the study are addressed once again along with associated hypotheses, expected outcomes of the study, research design which includes participants and sampling, instruments, and procedure, followed by the method of data analysis, and chapter summary.

Research Questions and Hypotheses

The primary question guiding this dissertation study is how music learning experiences relate to learning with multimedia in non-music disciplines. More specifically, the current study will investigate the following two, main research questions:

RQ1: To what extent do years of music learning experience, type of music learning experience, or type of multimedia in terms of segmentation predict task scores in a non-music task?
RQ2: To what extent do years of music learning experience, type of music learning experience, or type of multimedia in terms of segmentation predict task duration in a non-music task?

By responding to these two main research questions, the following sub-questions will likewise be addressed:

1. How do the years of prior music learning predict learning, measured by task score in a multimedia lesson?
2. How do the years of prior music learning predict learning, measured by task duration in a multimedia lesson?
3. How does the type of prior music learning predict learning, measured by task score in a multimedia lesson?
4. How does the type of prior music learning predict learning, measured by task duration in a multimedia lesson?
5. How does the type of multimedia in terms of segmentation predict learning, measured by task score?
6. How does the type of multimedia in terms of segmentation predict learning, measured by task duration?

To respond to the two, aforementioned main research questions, the following null hypotheses are proposed:

\( H_{01} \): Years of music learning experience, type of music learning experience, or type of multimedia in terms of segmentation are not related to task scores in a non-music task.
H₀₂: Years of music learning experience, type of music learning experience, or type of multimedia in terms of segmentation are not related to task duration in a non-music task.

The alternative hypotheses, corresponding with these null hypotheses are as follows:

Hₐ₁: Years of music learning experience, type of music learning experience, or type of multimedia in terms of segmentation are related to task scores in a non-music task.

Hₐ₂: Years of music learning experience, type of music learning experience, or type of multimedia in terms of segmentation are related to task duration in a non-music task.

Variables

The independent variables in this study are years of music learning (continuous variable: 0+), type of music learning (categorical variable with two levels: instrumental and vocal), and type of multimedia (categorical variable: segmented and non-segmented). The dependent variables are task score (continuous variable and task duration (continuous variable). The dependent variables will test the strength of the relationship between the independent and dependent variables and will be measured by the amount of time spent on the multimedia task and the accuracy of the participants’ responses to eight questions that follow completion of the task.

Expected Outcomes

It is expected that years of music learning experience will be positively associated with task scores and negatively associated with task duration when using multimedia learning resources. Music learners develop a system of expectations, understandings, and
meaningful patterns in their understanding of musical ideas (Cross et al., 2008), and
cognitive functions are developed over time and are based on experience and repeated
practice (Gruhn & Rauscher, 2011). If there are commonalities across disciplines in terms
of the cognitive functions developed through music learning (e.g., competencies,
especially executive functioning), it is suggested that these skills can transfer from one
discipline to another (Gouzouasis et al., 2007; Guhn et al., 2019) thus impacting learning.

It is anticipated that type of music training will not have an effect on task score or
task duration when learning with multimedia. Research has shown that the process of
listening, singing, composing, and playing an instrument has an effect on the motor,
visual, auditory, spatial, and cognitive abilities (Hyde et al., 2009; Schlaug, 2015), but the
specific type of music training has not been shown to have an advantage over another in
terms of developing these skills.

Regarding multimedia type (segmented versus non-segmented), it is anticipated
that music learning experience will likely have a negative association when learning with
segmented multimedia resources. This expectation relates to the expertise reversal effect
where segmented information can be distracting and perceived as a waste of time for a
more expert learner (Bransford, 2000; Hinds, 1999; Kalyuga, 2013; Rey & Buchwald,
2011). As music learners routinely chunk musical elements into smaller units that are of a
cognitively manageable size as they strive to perfect difficult passages (Chi et al., 1982;
Ericsson et al., 1993, 2007), predetermined segmentation may not correspond with these
learners’ self-determined segmentation thus resulting in an expertise reversal effect.
Research Design

This experimental study uses quantitative data to test the relationship between the dependent variables of task score and task duration and the independent variables of years of music learning, type of music experience, and type of multimedia (segmented or non-segmented) as they pertain to learning with multimedia in a non-music discipline.

Participants and Sampling

Using G*Power (v. 3.1.9.4), the sample size was calculated at a minimum of 119 participants necessary for an effect size of 0.15 and a power of 0.95 based on multiple linear regression. Participants will be recruited via convenience sampling through existing professional contacts at two universities with multiple campuses in a mid-Atlantic state of the U.S., including music and non-music departments. Drawing from the population of these universities, students with or without music learning experience (duration and type) who are 18 years of age or older will be eligible to participate.

Study Setting

STEM disciplines have been the main focus of studies regarding the effectiveness of multimedia resources in learning (e.g., Alexander, 1992; Alexander et al., 1994; Dochy, 1992; Perkins & Salomon, 1989). The current study will use a modified interactive lesson about the importance of carbon in the environment. Participation will occur at a time and place of their choosing, resembling online learning. The lesson should take approximately 20 to 30 minutes to complete with the final assessment taking approximately 15 minutes.
Procedure

After receiving approval from the university’s Institutional Review Board (IRB), participants will be recruited via email (Appendix A). Participants will be informed as to the purpose of the study via a Recruitment Letter (Appendix B). Reminders will be sent to potential participants noting a two-week deadline to complete the survey (Appendix C). All participants must give online consent (Appendix D) before being directed to the demographic survey (Appendix E), music experience survey (Appendix F), and learning task with assessment questions (Appendix G). Participation will be voluntary with no monetary or course incentives offered to those that volunteer to be part of this study. Individuals will be provided a single point of access to the online consent form, questionnaires, learning resources, and related assessments via Qualtrics XM® survey software. Upon reading the consent, participants who proceed to the next page will be considered as giving consent. Qualtrics will then randomly assign participants to either one of the study groups: a segmented multimedia group or a non-segmented multimedia group.

Instruments

This study will use a questionnaire, a music learning experience questionnaire, and a learning task. The demographic questionnaire will include questions regarding academic major, age, and gender. The music learning experience questionnaire will include questions about years of music learning experience and type of music learning.

The lesson resource used in this study is borrowed from WQED and PBS Interactive Learning Media under a Creative Commons license. The learning task regards the importance of carbon to the oceans. The learning task (video lesson and a total of 10
assessment questions) is identical for both segmented- and non-segmented groups. However, the video lesson and assessment questions are segmented into three chunks for the segmented group.

**Data Analysis Plan**

All collected data will be analyzed in IBM® *SPSS®* version 27. Multiple linear regression (MLR) will be used for data analyses as it allows for predictions to be made about one variable (dependent variable) using information known about other variables (independent variables). MLRs assume that there is a linear relationship between the dependent variables and independent variables and that there are no major correlations between the independent variables. MLR will allow this study to identify the strength of the effect of years of music learning, type of music learning, and type of multimedia (independent variables) on the task scores and task duration (dependent variables). It will also help determine how much of a change occurs when the independent variables change, providing information on the potential advantages of music learning on successful learning in other disciplines.

There will be two MLR studies analyses conducted in this research study. The first multiple regression will evaluate the association between the independent variables (years of music learning, type of music learning, and type of multimedia) and task score. The second will evaluate how the independent variables (years of music learning, type of music learning, and type of multimedia) are associated with task duration.
Chapter IV
Results

Overview

The purpose of the current study was to answer the research question of how music learning relates to learning with multimedia in non-music disciplines. This experimental study tested 1) to what extent do years of music learning experience, type of music learning experience, and type of multimedia in terms of segmentation predict task scores in a non-music task and 2) to what extent do years of music learning experience, type of music learning experience, and type of multimedia in terms of segmentation predict task duration in a non-music task. This chapter focuses on presenting and discussing the findings related to the two primary research questions. The chapter begins with a description of the sample followed by a summary of the descriptive statistics including the test for assumptions necessary for conducting a multiple linear regression. The results and analysis of the multiple linear regressions used to respond to the research questions are presented next. The chapter concludes with an interpretation of the data and how it supports the research questions and hypothesis of this study.

Description of the Sample

A total of 171 participants from two separate universities (with multiple campuses throughout a mid-Atlantic state of the U.S.) completed the study. The number of females versus males that responded to the survey was disproportionate at 115 females and 56 males (67.251% versus 32.748%). A total of 120 participants (70.175%) responded they had music learning experience; among them, 4 participants (2.339%) listed music as their academic major. A total of 105 participants (61.403%) identified some areas of science as
their major while the remainder identified majors in the humanities, technology, and business. Upon giving consent, the participants were randomly assigned to either the non-segmented learning task or the segmented learning task. However, natural attrition resulted in an unbalanced sample: $n = 81$ (47.370%) in the non-segmented group and $n = 90$ (52.630%) in the segmented group.

A preliminary inspection of the data was conducted to determine whether any values highly differed from predicted values. These outliers can be the result of data entry errors, measurement errors, or genuinely unusual values. Outliers in this study were detected by visual inspection, scatterplots, and histograms. The dependent variables of task duration and task score were examined for abnormalities in values from the predicted values. In this study, task duration was predicted to be between 900 seconds (15 minutes) to 1500 seconds (25 minutes). There were several anomalies noted in task duration. After checking that these anomalies were not the cause of data entry or software measurement errors, it was determined that these were unusual values. These values can have a detrimental effect on the regression equation, lead to a reduction in accuracy of prediction, and/or have a significant effect on the line of best fit. Therefore, allowing for some leeway due to interruptions, internet connections, or other computer errors, it was determined that a total of 8 records would be removed changing $N = 171$ to $N = 163$ for this study. Table 1 contains a more detailed look and comparison of the demographics.
Table 1

Results from the Demographic and Music Learning Experience Survey

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<th>Characteristic</th>
<th>Number</th>
<th>Percent</th>
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<td>N=171</td>
<td>N=163</td>
<td>N=171</td>
<td>N=163</td>
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<td>Sex as assigned at birth</td>
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<td>47</td>
<td>29.824</td>
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<td>0.613</td>
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</table>

Preliminary Data Analysis

Assumptions of multiple linear regression

Multiple linear regression makes certain assumptions about the relationships between the variables: 1) that the relationship between independent and dependent variables is linear (linearity), 2) that residuals should be normally distributed (multivariate normality), 3) that the variance of residuals should be same for all predicted responses (homoscedasticity), and 4) that no variable has a large overall influence
( multicollinearity ). Results of the testing for these assumptions are presented in the following paragraphs and charts.

Testing the dependent variable of task score for linearity, results show that there were six records identified as being more than ±3 standard deviation points away from the predicted value. This number was only 4% of the sample and should not significantly affect the outcome of the multiple linear regression. A second test for linearity was conducted for the dependent variable of task duration. The results were four records showing residuals with more than ±3 points from the standard deviation. This was a small amount (2.000%) in relation to the total sample and would be of no consequence to the outcome of the multiple linear regression. No action was needed to remove records.

The sample was tested for multicollinearity for both task duration and task score. The tolerance levels of 0.648, 0.645, and 0.995 ( task score ) and 0.648, 0.465 and 0.995 ( task duration ) were close to the recommended value of 1 and demonstrate the independent variables do not explain the variance in the dependent variables of task score and task duration. Again, no action was needed to adjust the sample.

To assess the shape and spread of the data distribution, a histogram, regression plot, and a scatter plot were created. Figure 7a is a histogram showing task score with a slightly left-skewed distribution of data ( \( N = 163, \bar{x} = 7.88E-17, SD = 0.991 \) ). Figure 7b is a residual plot illustrating a moderate positive linear relationship between the predicted task scores and the actual task scores. The final chart, Figure 7c, is a scatter plot that shows the sample ( \( N = 163 \) ) contains variations that are outside the fit line.
Figure 7

*Histogram, Regression Plot, and Scatter Plot for Task Score*

(a) Histogram of task score

(b) Regression plot of predicted task scores and actual task scores

(c) Scatter plot showing variation in sample
The shape and spread of the data distribution, a histogram, regression plot, and a scatter plot were also created for task duration. Figure 8a is a histogram showing task duration with a slightly right-skewed distribution of data ($N = 163, \bar{x} = -8.59E-17, SD = 0.991$). Figure 8b is a residual plot illustrating a moderate non-linear relationship between the predicted task scores and the actual task scores. Figure 8c is a scatter plot that shows the sample ($N = 163$) contains multiple variations that are outside the fit line.
Figure 8

Histogram, Regression Plot, and Scatter Plot for Task Duration

(a) Histogram of task duration

(b) Regression plot of predicted task duration and actual task duration

(c) Scatter plot showing variation in sample
Descriptive Statistics

Task Score

Descriptive statistics for task score were examined to gain information regarding
the variables of interest in the data set. As only one participant was in the vocal only
group, a decision was made to exclude that case from further analysis resulting in \( N = 162 \). Individuals with more years of music learning experience (e.g., 6 to 10 and 10+
years) showed higher task scores \((n = 46, \bar{x} = 8.070, SD = 1.124; n = 41, \bar{x} = 8.050, SD = 1.203\), respectively). As for type of music learning experience, the group that had both
instrumental and vocal learning showed the highest task score \((n = 40, \bar{x} = 8.030, SD = 1.250\). Task score for each type of multimedia were similar for the non-segmented \((n = 78, \bar{x} = 7.600, SD = 1.738\) and segmented groups \((n = 84, \bar{x} = 7.710, SD = 1.602\). Table
2 summarizes the descriptive statistics for the task scores.

Table 2

Mean and Standard Deviation of Task Score by Years of Music Learning, Type of Music
Learning, and Type of Multimedia

<table>
<thead>
<tr>
<th></th>
<th>( n )</th>
<th>Min</th>
<th>Max</th>
<th>( \bar{x} )</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Years of MLE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 to less than 1</td>
<td>51</td>
<td>0</td>
<td>9</td>
<td>6.920</td>
<td>2.244</td>
</tr>
<tr>
<td>1 to 5</td>
<td>24</td>
<td>5</td>
<td>9</td>
<td>7.790</td>
<td>1.285</td>
</tr>
<tr>
<td>6 to 10</td>
<td>46</td>
<td>4</td>
<td>9</td>
<td>8.070</td>
<td>1.124</td>
</tr>
<tr>
<td>10+</td>
<td>41</td>
<td>4</td>
<td>9</td>
<td>8.050</td>
<td>1.203</td>
</tr>
<tr>
<td>Type of MLE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>47</td>
<td>0</td>
<td>9</td>
<td>6.850</td>
<td>2.236</td>
</tr>
<tr>
<td>Both (instrumental &amp; vocal)</td>
<td>40</td>
<td>4</td>
<td>9</td>
<td>8.030</td>
<td>1.250</td>
</tr>
<tr>
<td>Instrumental music experience only</td>
<td>75</td>
<td>4</td>
<td>9</td>
<td>7.970</td>
<td>1.230</td>
</tr>
<tr>
<td>Type of MM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-segmented</td>
<td>78</td>
<td>0</td>
<td>9</td>
<td>7.600</td>
<td>1.738</td>
</tr>
</tbody>
</table>
Task Duration

Descriptive statistics for task duration were examined to gain information regarding the variables of interest in the data set. The 10+ years of music learning experience group spent the shortest time on the learning task ($n = 41, \bar{x} = 697.240, SD = 265.253$). As for the type of music learning experience, the group identified as having both instrumental and vocal learning spent less time on the learning task compared with the other groups ($n = 40, \bar{x} = 802.600, SD = 325.463$). Time on task for each type of multimedia was similar for the non-segmented ($n = 78, \bar{x} = 852.130, SD = 815.028$) and segmented groups ($n = 84, \bar{x} = 903.770, SD = 889.196$). Descriptive statistics for task duration are summarized in Table 3.

Table 3

*Mean and Standard Deviation of Task Duration in Seconds by Years of Music Learning, Type of Music Learning, and Type of Multimedia*

<table>
<thead>
<tr>
<th>Years of MLE</th>
<th>n</th>
<th>Min</th>
<th>Max</th>
<th>$\bar{x}$</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to less than 1</td>
<td>51</td>
<td>144</td>
<td>4993</td>
<td>911.530</td>
<td>1070.545</td>
</tr>
<tr>
<td>1 to 5</td>
<td>24</td>
<td>346</td>
<td>4359</td>
<td>1053.380</td>
<td>870.708</td>
</tr>
<tr>
<td>6 to 10</td>
<td>46</td>
<td>259</td>
<td>5218</td>
<td>913.630</td>
<td>908.407</td>
</tr>
<tr>
<td>10+</td>
<td>41</td>
<td>336</td>
<td>1595</td>
<td>697.240</td>
<td>265.253</td>
</tr>
<tr>
<td>Type of MLE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>47</td>
<td>144</td>
<td>4993</td>
<td>923.770</td>
<td>1108.896</td>
</tr>
<tr>
<td>Both (instrumental &amp; vocal)</td>
<td>40</td>
<td>336</td>
<td>1923</td>
<td>802.600</td>
<td>325.463</td>
</tr>
<tr>
<td>Instrumental music experience only</td>
<td>75</td>
<td>259</td>
<td>5218</td>
<td>891.490</td>
<td>868.735</td>
</tr>
</tbody>
</table>

Note. MLE: Music Learning Experience, MM: Multimedia
Main Data Analyses

Multiple Linear Regression of Task Scores

Multiple linear regression was used to test if years of music learning experience, type of music learning experience, and type of multimedia significantly predicted task scores.

\[ Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \epsilon \]

The fitted regression model was: Task score = 6.764 + 0.033 * (Years_{MLE}) + 0.902 * (Instrumental) + 0.942* (Both) + 0.101 * (Type_{MM}).

The dependent and independent variables in the equation are defined as follows:

- Task score is measured on a numeric scale.
- Years_{MLE}: Years of music learning experience are measured
  0 for no years of music learning experience,
  1 for less than 1 year of experience, 2 for 1 to 2 years of experience,
  3 for 2 to 3 years of experience, 4 for 3 to 4 years of experience,
  5 for 4 to 5 years of experience, 6 for 5 to 6 years of experience,
  7 for 6 to 7 years of experience, 8 for 7 to 8 years of experience,
  9 for 8 to 9 years of experience, 10 for 9 to 10 years of experience, and
  11 for more than 10 years of experience.
• **Type\textsubscript{MLE}:** Type of music learning experience is coded as 1 both instrumental and vocal experience, 2 for instrumental experience, 3 for no musical learning experience.

• **Type\textsubscript{MM}:** Type of multimedia is coded as 1 for non-segmented and 2 for segmented.

The overall regression was statistically significant ($Adj.R^2 = 0.079$, $F(4,157) = 4.434$, $p = 0.002$). The model accounted for 7.9% of the variation in task score. The linear regression model indicated that type of music learning experience ($\beta = 0.902$, $p = 0.044$ for the instrumental music learning group and $\beta = 0.942$, $p = 0.050$ for those with both instrumental and vocal learning) were predictors of task score. The independent variables of type of multimedia and years of music learning experience were not significant predictors of task score as indicated in Table 4.

### Table 4


tabular| \(\beta\) & SE & \(B\) & \(t\) & \(p\) |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>6.764</td>
<td>0.270</td>
<td></td>
<td>25.019</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Years\textsubscript{MLE}</td>
<td>0.033</td>
<td>0.048</td>
<td>0.081</td>
<td>0.687</td>
<td>0.493</td>
</tr>
<tr>
<td>Instrumental only</td>
<td>0.902</td>
<td>0.444</td>
<td>0.271</td>
<td>2.030</td>
<td>0.044</td>
</tr>
<tr>
<td>Both</td>
<td>0.942</td>
<td>0.477</td>
<td>0.245</td>
<td>1.976</td>
<td>0.050</td>
</tr>
<tr>
<td>Type\textsubscript{MM}</td>
<td>0.101</td>
<td>0.255</td>
<td>0.031</td>
<td>0.398</td>
<td>0.691</td>
</tr>
</tbody>
</table>

Addressing the Sub-questions for Task Score

This study also included three sub-questions that sought to determine whether the independent variables, separately, were able to predict task score. Each individual sub-question was further examined to identify potential trends as follows.

**How do the years of prior music learning predict learning, measured by task score in a multimedia lesson?**

The findings of the multiple regression for task score indicated that years of music learning experience was not a significant predictor of task score. However, a trend can be seen where, as years of music experience increases, task scores likewise increase (Table 2).

**How does the type of prior music learning predict learning, measured by task score in a multimedia lesson?**

The findings of the multiple regression for task score indicated that type of music learning experience was a significant predictor of task score. Those who had instrumental music learning as well as both instrumental and voice experience showed significantly greater task scores versus those with no music learning experience (Table 2).

**How does the type of multimedia in terms of segmentation predict learning, measured by task score?**

The findings of the multiple regression for task score indicated that type of multimedia (segmented or non-segmented) was not a significant predictor of task score. Both groups showed fairly equivalent task scores (Table 2).
**Multiple Linear Regression of Task Duration**

A second multiple linear regression was conducted to examine if years of music learning experience, type of music learning experience, and type of multimedia predicted task duration.

\[ Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \epsilon \]

The fitted regression model was: Task duration = 920.040 - 45.072 * (YearsMLE) + 282.585 * (Instrumental) + 188.131 * (Both) + 91.740 * (TypeMM).

The dependent and independent variables in the equation are defined as follows:

- Task score is measured on a numeric scale.
- **YearsMLE**: Years of music learning experience are measured 0 for no years of music learning experience,
  1 for less than 1 year of experience, 2 for 1 to 2 years of experience,
  3 for 2 to 3 years of experience, 4 for 3 to 4 years of experience,
  5 for 4 to 5 years of experience, 6 for 5 to 6 years of experience,
  7 for 6 to 7 years of experience, 8 for 7 to 8 years of experience,
  9 for 8 to 9 years of experience, 10 for 9 to 10 years of experience, and
  11 for more than 10 years of experience.
- **TypeMLE**: Type of music learning experience is coded as 1 both instrumental and vocal experience, 2 for instrumental experience, 3 for no musical learning experience.
- **TypeMM**: Type of multimedia is coded as 1 for non-segmented and 2 for segmented.
The overall regression was not statistically significant \((\text{Adj. } R^2 = -0.001, F(4,157) = 0.945, p = 0.439)\). The linear regression for task duration found that, together, the independent variables of type of multimedia, years of music learning experience and type of music learning experience (instrumental music learning group and both instrumental and vocal learning) were not significant predictors of task duration as summarized in Table 5.

### Table 5

**Confidence Levels of Independent Variables on Task Duration**

<table>
<thead>
<tr>
<th></th>
<th>β</th>
<th>SE</th>
<th>B</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>920.040</td>
<td>144.238</td>
<td>6.379</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Years\textsubscript{MLE}</td>
<td>-45.072</td>
<td>25.441</td>
<td>-0.218</td>
<td>-1.772</td>
<td>0.078</td>
</tr>
<tr>
<td>Instrumental only</td>
<td>282.585</td>
<td>237.083</td>
<td>0.166</td>
<td>1.192</td>
<td>0.235</td>
</tr>
<tr>
<td>Both</td>
<td>188.131</td>
<td>254.235</td>
<td>0.096</td>
<td>0.740</td>
<td>0.460</td>
</tr>
<tr>
<td>Type\textsubscript{MM}</td>
<td>91.740</td>
<td>135.947</td>
<td>0.054</td>
<td>0.675</td>
<td>0.501</td>
</tr>
</tbody>
</table>


**Addressing the Sub-questions for Task Duration**

This study also included three sub-questions that sought to determine whether the independent variables, separately, were able to predict task duration. Each individual sub-question was further examined to identify potential trends as follows.

**How do the years of prior music learning predict learning, measured by task duration in a multimedia lesson?**

The findings of the multiple regression indicated that years of music learning experience was not a significant predictor of task duration. A trend, however, can be seen
where those with more years of music learning experience (e.g., greater than 5 years) appeared to spend less time on the task (Table 3).

**How does the type of prior music learning predict learning, measured by task duration in a multimedia lesson?**

The findings of the multiple regression indicated that type of music learning experience was not a predictor of task duration. While mean task duration did differ among the groups, no clear trends were observed (Table 3).

**How does the type of multimedia in terms of segmentation predict learning, measured by task duration?**

The findings of the multiple regression for task duration indicated that type of multimedia (segmented or non-segmented) was not a significant predictor of task duration. Both groups showed fairly equivalent task durations (Table 3).

**Addressing the Research Questions**

**Research Question 1**

The null hypothesis for Research Question 1 states that the years of music learning experience, type of music learning experience, and type of multimedia in terms of segmentation are not related to task scores in a non-music task. The overall regression model was statistically significant, where type of music learning experience, namely the instrumental group and the instrumental and vocal group, were predictors of task score. The data thus provides support for the alternative hypothesis.

**Research Question 2**

The null hypothesis for Research Question 2 states that the years of music learning experience, type of music learning experience, and type of multimedia in terms
of segmentation are not predictors of task duration in a non-music task. The overall regression model was not statistically significant. The data thus provides support for the null hypothesis.

**Summary**

The purpose of the current study was to respond to the research question of how music learning relates to learning with multimedia in non-music disciplines. This experimental study tested 1) to what extent do years of music learning experience, type of music learning experience, and type of multimedia in terms of segmentation predict task scores in a non-music task and 2) to what extent do years of music learning experience, type of music learning experience, and type of multimedia in terms of segmentation predict task duration in a non-music task. With a final sample size of 162 participants, data were collected via an online demographic survey, a music learning experience survey, and a learning task with success measured by task scores and task duration. Two multiple linear regressions were conducted to determine whether the independent variables of years of music learning experience, type of music learning experience, and type of multimedia were predictors of the dependent variables of task score and task duration.

Multiple linear regressions revealed that type of music learning experience was a predictor of task score. None of the independent variables, however, successfully predicted task duration. Chapter 5 will evaluate and interpret the results of this study. It will discuss the results and draw conclusions about the implications for further research.
Chapter V

Conclusions

The purpose of the study was to investigate how music learning relates to learning with multimedia in non-music disciplines. This experimental study tested (1) to what extent do years of music learning experience, type of music learning experience, and type of multimedia in terms of segmentation predict task scores in a non-music task and (2) to what extent do years of music learning experience, type of music learning experience, and type of multimedia in terms of segmentation predict task duration in a non-music task.

Summary of Procedures

Participants were recruited through contacts and emails at two universities with multiple campuses throughout a mid-Atlantic state of the U.S. Upon giving consent to voluntarily participate in the online study, participants completed the demographic questions and music learning experience questions. They were then randomly assigned into one of the study groups: segmented (learning content and assessment were split into three segments) or non-segmented (all learning content and assessment were offered at once). Task scores and task duration were recorded for both groups while they completed the online learning task.

Participants and Demographics

Although 171 individuals completed their participation, following removal of outliers and abnormal cases, only 162 participant responses were used for the main data analyses. Females were overrepresented in the study. The majority of participants were aged 30 and over, science majors, and had some music learning experience.
Summary of Findings

Research Question 1

The first research question asked if years of music learning experience, type of music learning experience, and type of multimedia in terms of segmentation significantly predicted task scores. The findings showed that, while the overall regression model was statistically significant, only type of music learning experience was a predictor of task score.

Research Question 2

The second research question asked if years of music learning experience, type of music learning experience, and type of multimedia in terms of segmentation significantly predicted task duration. The analysis revealed that the overall regression model was not statistically significant.

Findings as Related to the Literature

Existing literature indicates that music learning experience has positive impacts on various aspects of individual development (e.g., cognitive functions, emotional development, life skills, etc.) (Hyde et al., 2009; Schlaug, 2015). Whether playing an instrument or singing, music engages memory, recognition of patterns, and coordination of a variety of mental and physical abilities (Dalla Bella, 2016; Jäncke, 2009; Menon et al., 2007). In addition to the cognitive advantages, learning music also offers further advantages such as time management and organizational skills (Schellenberg, 2005; Pascual-Leone, 2001; Patel, 2010; Schlaug et al., 2005; Weinberger, 1998). The literature, however, seldom differentiates between types of music learning. The findings revealed that, regardless of type, music learning experience did have a positive
association with task scores but not task duration. This study supports the literature that music learning is beneficial to one’s cognitive abilities (e.g., Hyde et al., 2009; Schlaug, 2015).

The cognitive engagement required in learning music has shown to transfer to other domains such as mathematics, science, and English (Gouzouasis et al., 2007; Guhn et al., 2019). As cognitive functions are developed over time and are based on experience and repeated practice (Gruhn & Rauscher, 2011), it could be assumed that the benefits of music learning experience would increase with years of music learning experience. The study findings, however, revealed that years of music learning experience did not predict task scores or task duration. It is nonetheless worth noting that task scores showed an upward trend as years of experience increased, whereas task durations showed a downward trend as years of experience increased. While the lack of statistically significance contradicts the literature regarding the cognitive advantages of music learners (e.g., Gouzouasis et al., 2007; Guhn et al., 2019), the trends observed in this study do offer some insights into the benefits of continued music learning experience. However, it is interesting that, while music learning experience is a predictor of cognitive performance, years of music learning experience is not.

Music learners are trained to routinely chunk musical elements into smaller units that are of a cognitively manageable size as they strive to perfect difficult passages, playing them over and over again (Chi et al., 1982; Ericsson et al., 1993, 2007). Segmenting is also often used when presenting new content to learners to reduce the cognitive load to be managed at any given point in time (Mayer & Fiorella, 2014). For individuals with content expertise, however, segmented learning resources have been
shown to be distracting and perceived as a waste of their time, thus resulting in the expert reversal effect (Bransford, 2000; Hinds, 1999; Kalyuga, 2013; Rey & Buchwald, 2011). It may thus also be that music learners may experience an expertise reversal effect from segmented content given their potentially well-developed skills at independently segmenting content. The findings from the current study revealed that the type of multimedia in terms of segmentation was not a predictor of task scores or task duration, regardless of music learning experience. This implies that the expertise reversal effect is linked to content knowledge, but not the skill of independently segmenting information.

**Delimitations and Limitations of Study**

By analyzing how music learning relates to learning with multimedia in non-music disciplines, this study investigated how individuals with diverse music learning experiences transfer their learning strategies (e.g., chunking and segmenting) to the acquisition of new knowledge using multimedia learning resources in non-music disciplines, which had been otherwise unexplored. However, this study is delimited in that participants were recruited from two local universities rather than the larger general population of the area. It would have been of benefit to widen the recruitment to other areas of life experience beyond that of universities (e.g., trade schools, community colleges, people in the job market, etc.). A second delimitation is that the participants completed the study at a time and location of their choosing. There were a number of records that were left open and unfinished due to unknown reasons.

This study had several limitations that may have influenced the validity and reliability of the data collected. First, the majority of participants were females, over 30 years of age, and science majors. Second, there were cases with extremely long task
durations, which may have been caused by participants not closing the survey window once having completed the learning task, computers malfunctioning, or participants deciding to not complete the task. An additional reminder or an automatic closure to the study might have been added after the last question had been answered to prevent the overly long task durations beyond the expected time frame for completion.

**Recommendations for Future Research**

The findings from the current study, as well as the delimitations and limitations, offer meaningful suggestions for future research studies. The following recommendations are offered as ways in which the research begun by this study could be expanded upon.

First, using a large, stratified sampling for academic majors would make it possible to compare the varied disciplines’ approaches to the multimedia learning task and how their success rates differed. Each academic major could also be divided into those with and those without music learning experience and task scores and task durations compared within grouped disciplines. A comparison could be made as to how these varied groups approach the multimedia learning task and how their success rates differ.

Second, the adoption of tasks from diverse disciplines (e.g., STEM and non-STEM disciplines) would allow comparison of findings to determine whether music learning experience has similar influences on the transfer of their strategies to different subjects. Providing an option for a learning task that is outside participants’ stated discipline could have the effect of leveling the prior knowledge advantage. Having all the participants at the novice stage of the learning task may provide different outcomes for
both task score and task duration allowing for inferences to be drawn about the expert
reversal effect when using segmented multimedia instruction.

Third, it could also be suggested that future research be conducted in a more
controlled environment to help ensure the accuracy of data as it relates to task duration
given the use of standardized computer processes and networks.

Fourth, this study used a multiple linear regression to examine the relationship
between the dependent variables (task scores and task duration) and the independent
variables (years of music learning experience, type of music learning experience, and
type of multimedia). Future research could pursue a greater sample size and analyze such
data via different means (e.g., MANOVA), which may potentially yield different
findings.

Fifth, years of music earning experience and the benefit of studying music was a
main interest in this study. To investigate when and how the changes and benefits of
music learning occur, it is suggested that a longitudinal study using younger learners in
K-12 could be conducted to examine at what point music learning impacted learning
performance in non-music disciplines.

Future studies using the above suggestions could add to the knowledgebase of
how and when the positive benefits of music learning become apparent when learning in
non-music disciplines with multimedia resources.

Conclusions

The goal of this study was to explore the question of whether years of music
learning experience, type of music learning experience, or type of multimedia were
associated with task scores and task duration in a non-music discipline. The study
revealed the transferable benefits of music learning experience to learning outcomes in other disciplines. Encouraging music studies as part of the base curriculum is thus strongly encouraged. However, as years of music learning and the presence or absence of segmenting in multimedia learning resources were not found to associate with learning outcomes, it may be worthwhile to examine other potential factors that are developed as a byproduct of music learning.
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https://doi.org/10.1016/j.sbspro.2015.02.304


https://doi.org/(Original manuscripts [ca. 1930-1934])


https://doi.org/10.1038/434312a

Appendix A

Email to Faculty

Dear Faculty,

Thank you for volunteering to help my research and become the recruiter/liaison. As was communicated, the purpose of this study is to investigate how prior music learning experience relates to learning with multimedia resources in non-music disciplines. It will investigate whether cognitive strategies trained via music learning transfer to a non-music discipline by uncovering the association, or the lack thereof, that varying degrees of prior music learning, types of the music learning experience, and multimedia learning resource types associate with student learning performance. To be a participant, the individual should be 18 years old or older, with or without prior musical training experience.

Please share the recruitment letter attached to this email with your students. Please also forward this email to other instructors in your department.

Sincerely,

[Enter URL to study here.]
Appendix B

Recruitment Email

Dear Prospective Participant,

My name is Cheryl Farren Tkacs and I am a doctoral candidate in Educational Technology at Duquesne University, Pittsburgh, PA. I am writing to invite you to participate in my research study which aims to investigate how varying levels of music learning experience relates to learning with multimedia resources in non-music disciplines. Prior music learning experience is NOT required to participate in the study.

If you provide your consent to participate, you will be asked to answer questions about your demographics (i.e., academic major, age, gender) and music learning experience (i.e., years and types of music learning). You will then be asked to complete a learning task about the importance of carbon in the oceans. During the task, you will be asked a total of 10 questions about the information presented. Your time on task and task score will be recorded.

The only qualification for participation is that you must be 18 years or older. As part of the study, you will be randomly assigned to one of two study groups. If you are interested in the study, please click on the link provided below to begin the study.

[Enter URL here]

You can withdraw from the study at any time. If you'd like to participate but have questions about the study, please feel free to contact me through email.

Thank you for your consideration.

Sincerely,
Appendix C

Reminder Email

Dear [Name],

Thank you again for your help in recruiting participants for my study. To ensure as many individuals as possible in this research, would you be so kind as to send a reminder that there is still two (2) weeks left to participate in the study? I am attaching the Letter to Participants for you to forward with your email.

Sincerely,
Appendix D

Consent Form

DUQUESNE UNIVERSITY
PITTSBURGH, PENNSYLVANIA

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

TITLE:
Implications of Individuals with Music Learning Experience Using a Segmented Multimedia Lesson in a Non-Music Discipline

INVESTIGATOR:
Cheryl Farren Tkacs
School of Education
tkacsc1@duq.edu

ADVISOR:
Misook Heo, Ph.D.
Professor
School of Education
heom@duq.edu

PURPOSE:
The purpose of this study is to investigate how prior music learning experience relates to learning with multimedia resources in non-music disciplines. The study will examine whether and how much varying degrees of and types of music learning experience are associated with performance in a learning task about the importance of carbon in the oceans.

PARTICIPANT PROCEDURES:
You must be 18 years or older to participate in the study. You do not have to have any music learning experience. As part of the study, you will be randomly assigned to one of two study groups.
If you provide your consent to participate, you will be asked to answer questions about your demographics (i.e., gender, academic major, age) and music learning experience (i.e., years and types of music learning experience). You will then be asked to complete a learning task about the importance of carbon in the oceans, which is borrowed from WQED and PBS Interactive Learning Media under a Creative Commons license. During the task, you will be asked a total of 10 questions about the information presented. Your time on task and task score will be recorded. Your participation should take about 30 minutes.

RISKS AND BENEFITS:

There are no risks greater than those encountered in everyday life. The main benefit of participating in this is contributing to the knowledge about transferability of strategies gained from music learning to learning in other disciplines.

COMPENSATION:

There is no compensation provided by the researcher for participating in this study. Participation in the project will require no monetary cost to you.

CONFIDENTIALITY:

Your personal information, including your name, will never be collected in or appear on any survey or research instruments. Your response(s) will only appear in statistical data summaries. Therefore, no one will be able to determine how you responded.

All electronic data collected will be kept secure. All data will be maintained for five years after the completion of the data collection and then destroyed.

RIGHT TO WITHDRAW:

You are under no obligation to start or continue this study. You can withdraw at any time without penalty or consequence by not completing the survey. If you withdraw after completing the survey, the researcher has no choice but to include the data for data analysis because there is no way to identify your responses.

All completed anonymous data already collected will be kept for the study.
SUMMARY OF RESULTS:

A summary of the results of this study will be provided to you at no cost. You may request this summary by contacting the researcher and requesting it. The information provided to you will not be your individual responses, but rather a summary of what was discovered during the research project.

VOLUNTARY CONSENT:

I have read this informed consent form and understand what is being requested of me. I also understand that my participation is voluntary and that I am free to withdraw at any time, for any reason without any consequences. Based on this, I certify I am willing to participate in this research project.

I understand that if I have any questions about my participation in this study, I may contact Cheryl Farren Tkacs at 724.309.2760 or at tkacsc1@duq.edu. If I have any questions regarding my rights and protections as a subject in this study, I can contact Dr. David Delmonico, Chair of the Duquesne University Institutional Review Board for the Protection of Human Subjects at 412.396.1886 or at irb@duq.edu.

Duquesne University’s Institutional Review Board has approved/verified this research study

If you proceed to the next page, it indicates that you have agreed to consent to your participation in the research study.
Appendix E

Demographic Survey

1. What is your academic major?
   
   2. What is your age?
   
   3. What sex were you assigned at birth (on your original birth certificate)?
      a. Male
      b. Female

4. Have you ever studied music?
   a. No
   b. Yes
Appendix F

Music Learning Experience Survey

1. If you have studied music, please indicate approximately how many years of music learning you have.

2. Please indicate your primary musical learning experience.
   a) Private instruction
   b) Classroom instruction (school)
   c) Self-taught
   d) Online tutorials
   e) Community music groups
   f) Other (please type in where you received your training)

3. Please indicate all your musical training.
   a) String Family
   b) Woodwind Family
   c) Brass Family
   d) Percussion Family
   e) Keyboard Instruments
   f) Vocal
   g) Other

   String Family
   a) Violin
   b) Viola
   c) Cello
   d) Bass
   e) Harp
   f) Other (please be specific)

   Woodwind Family
   a) Flute/Piccolo
   b) Oboe/English horn
   c) Clarinet/E flat/bass
   d) Bassoon/contrabassoon
   e) Saxophone (alto/tenor/baritone
   f) Other (please be specific)
Brass Family
a) Trumpet/coronet
b) French horn
c) Baritone/euphonium
d) Trombone
e) Tuba/Sousaphone
f) Other (please be specific)

Percussion Family
a) Drums (Timpani/snare/bass)
b) Cymbals/tambourine/triangle
c) Xylophone
d) Glockenspiel
e) Chimes/Marimba/Vibraphone
f) Other (please be specific)

Keyboard Instruments
a) Piano
b) Harpsichord
c) Organ
d) Celesta
e) Synthesizer
f) Other (please be specific)

Vocal
a) I perform with a group/ensemble
b) I do solo performances

c) Keyboard Instruments

4. Please note other musical training not listed above.
Appendix G

Learning Tasks

Segmented Tutorial

Please review the following three learning videos. There are questions to respond to after each video (for a total of 10).

Video 1 Introduction

1. Which of these statements is not true?
   a) Carbon is detrimental to human life.
   b) Carbon is one of the building blocks of life.
   c) Carbon is the most abundant chemical element.
   d) Carbon is involved in photosynthesis and respiration.

2. Carbon
   a) must be removed from the atmosphere.
   b) is an element that is dangerous to all life on earth.
   c) is only found in the oceans.
   d) is a major factor in energy producing processes.
Video 2 The Solubility Pump

3. When cold dry air passes over the oceans
   a) the oceans keep their heat from the warm water far below the surface.
   b) the warm waters are able to absorb more carbon dioxide from the atmosphere.
   c) the ocean surface loses heat to the atmosphere.

4. Which of the following statements best describe the solubility pump.
   a) Cold dry air passes over the warmer ocean waters.
      Cool ocean water is able to absorb more carbon dioxide from the atmosphere.
      Cool ocean water becomes dense and sinks into the deeper interior ocean.
      Carbon dioxide eventually returns to the surface where there is upwelling.
      Ocean water is warmed by the sun, carbon dioxide decreases in the water and goes into the atmosphere.
   b) Warm dry air passes over the ocean waters.
      Warm waters of the ocean evaporate carbon dioxide into the atmosphere.
      Cool ocean water becomes dense and sinks into the deeper interior ocean.
      Carbon dioxide eventually returns to the surface where there is upwelling.
      Ocean water is warmed by the sun, carbon dioxide decreases in the water and goes into the atmosphere.
   c) Cold dry air passes over the warmer ocean waters.
      Cool ocean water is able to absorb more carbon dioxide from the atmosphere.
      Cool ocean water becomes dense and sinks into the deeper interior ocean.
      Upwellings keep carbon dioxide in the lower depths of the ocean to prevent harm to plants and animals.
      Ocean water is warmed by the sun, carbon dioxide decreases in the water and goes into the atmosphere.
5. Cold dense water can remain in the ocean depths for
   a) 24 hours
   b) 1 year
   c) Thousands of years

6. An upwelling is
   a) the ocean releasing oxygen into the air.
   b) a process in which deep cold water rises toward the surface.
   c) the point where the solubility and biological pumps work together.

**Video 3 The Biological Pump**

7. Phytoplankton in the oceans
   a) need oxygen to photosynthesize.
   b) exhale carbon dioxide into the oceans.
   c) are a source of food for zooplankton.

8. Which of the following statements best describe the biological pump.
   a) Phytoplankton needs the oxygen in the oceans to photosynthesize, grow, and reproduce.
      Zooplankton eat Phytoplankton exhaling, ingesting, and returning some carbon dioxide to the water.
      Uneaten plankton break up and dissolve in the ocean releasing oxygen back into the water.
The high levels of carbon dioxide are returned to the atmosphere at upwelling sites.

b) Phytoplankton uses carbon dioxide in the oceans to photosynthesize. Zooplankton eat phytoplankton returning carbon dioxide to the water in the process. Uneaten plankton clumps together and sinks to the bottom of the ocean to be eaten releasing carbon dioxide into the water. High levels of oxygen are released to the atmosphere at upwelling sites.

c) Phytoplankton uses carbon dioxide in the oceans in photosynthesis. Zooplankton in the process of eating Phytoplankton return carbon dioxide to the water. Uneaten plankton clumps and sinks to the bottom of the ocean to be eaten by other animals releasing carbon dioxide into the ocean. Carbon dioxide is returned to the atmosphere at upwelling sites.

9. The solubility and biological pumps work in tandem to move carbon through the oceans.
   a) True
   b) False

10. The purpose of the solubility and the biological pumps is to keep the carbon dioxide in the oceans below the surface so it does not evaporate into the atmosphere.
    a) True
    b) False
Non-Segmented Tutorial

Please review the following learning video. There are questions to respond to after the video (a total of 10).

Combined Video

![Image](https://example.com/combined_video.png)

**Combined Video Caption:** Carbon is known as the king of elements.

1. Which of these statements is **not** true?
   a) Carbon is detrimental to human life.
   b) Carbon is one of the building blocks of life.
   c) Carbon is the most abundant chemical element.
   d) Carbon is involved in photosynthesis and respiration.

2. Carbon
   a) must be removed from the atmosphere.
   b) is an element that is dangerous to all life on earth.
   c) is only found in the oceans.
   d) is a major factor in energy producing processes.

3. When cold dry air passes over the oceans
   a) the oceans keep their heat from the warm water far below the surface.
   b) the warm waters are able to absorb more carbon dioxide from the atmosphere.
   c) the ocean surface loses heat to the atmosphere.
4. Which of the following statements best describe the solubility pump.
   a) Cold dry air passes over the warmer ocean waters. 
      Cool ocean water is able to absorb more carbon dioxide from the atmosphere. 
      Cool ocean water becomes dense and sinks into the deeper interior ocean. 
      Carbon dioxide eventually returns to the surface where there is upwelling. 
      Ocean water is warmed by the sun, carbon dioxide decreases in the water and 
      goes into the atmosphere.
   b) Warm dry air passes over the ocean waters. 
      Warm waters of the ocean evaporate carbon dioxide into the atmosphere. 
      Cool ocean water becomes dense and sinks into the deeper interior ocean. 
      Carbon dioxide eventually returns to the surface where there is upwelling. 
      Ocean water is warmed by the sun, carbon dioxide decreases in the water and 
      goes into the atmosphere.
   c) Cold dry air passes over the warmer ocean waters. 
      Cool ocean water is able to absorb more carbon dioxide from the atmosphere. 
      Cool ocean water becomes dense and sinks into the deeper interior ocean. 
      Upwellings keep carbon dioxide in the lower depths of the ocean to prevent 
      harm to plants and animals. 
      Ocean water is warmed by the sun, carbon dioxide decreases in the water and 
      goes into the atmosphere.

5. Cold dense water can remain in the ocean depths for
   a) 24 hours 
   b) 1 year 
   c) thousands of years 

6. An upwelling is
   a) the ocean releasing oxygen into the air. 
   b) a process in which deep cold water rises toward the surface. 
   c) the point where the solubility and biological pumps work together.

7. Phytoplankton in the oceans
   d) need oxygen to photosynthesize. 
   e) exhale carbon dioxide into the oceans. 
   f) are a source of food for zooplankton.

8. Which of the following statements best describe the biological pump.
   a) Phytoplankton needs the oxygen in the oceans to photosynthesize, grow, 
      and reproduce.
Zooplankton eat Phytoplankton exhaling, ingesting, and returning some carbon dioxide to the water. Uneaten plankton break up and dissolve in the ocean releasing oxygen back into the water. The high levels of carbon dioxide are returned to the atmosphere at upwelling sites.

b) Phytoplankton uses carbon dioxide in the oceans to photosynthesize. Zooplankton eat phytoplankton returning carbon dioxide to the water in the process. Uneaten plankton clumps together and sinks to the bottom of the ocean to be eaten releasing carbon dioxide into the water. High levels of oxygen are released to the atmosphere at upwelling sites.

c) Phytoplankton uses carbon dioxide in the oceans in photosynthesis. Zooplankton in the process of eating Phytoplankton return carbon dioxide to the water. Uneaten plankton clumps and sinks to the bottom of the ocean to be eaten by other animals releasing carbon dioxide into the ocean. Carbon dioxide is returned to the atmosphere at upwelling sites.

9. The solubility and biological pumps work in tandem to move carbon through the oceans.
   a) True
   b) False

10. The purpose of the solubility and the biological pumps is to keep the carbon dioxide in the oceans below the surface so it does not evaporate into the atmosphere.
    a) True
    b) False