CURRICULUM VITAE OF RAYNE MELISSA LODER, PA-C

rayneloder@gmail.com

EDUCATION

- UNIVERSITY OF MARYLAND, Baltimore, MD
  Doctor of Philosophy, **Health Professions Education**, 2025
  - Dissertation: The Effect of Song-based Instruction on First-Year Physician Assistant Students' Knowledge Acquisition

- LOCK HAVEN UNIVERSITY OF PENNSYLVANIA, Lock Haven, PA
  Master of Health Science, **Physician Assistant Studies**, May 2013

- LEBANON VALLEY COLLEGE, Annville, PA
  Bachelor of Science, **Biology**, May 2006

BOARD CERTIFICATIONS

- **NATIONAL COMMISSION ON CERTIFICATION OF PHYSICIAN ASSISTANTS** – Certified
  - 2013 – Present

STATE LICENSES

- **NEW HAMPSHIRE**, PHYSICIAN ASSISTANT LICENSE – Current
  2016 – Present
- **UTAH**, PHYSICIAN ASSISTANT LICENSE – Expired
  2019 – 2021
- **WASHINGTON**, PHYSICIAN ASSISTANT LICENSE – Expired
  2013 – 2021

ACADEMIC EXPERIENCE

Director of Interprofessional Education, 2023 – Present
Clinical Associate Professor of Public Health & Community Medicine
Tufts University School of Medicine Physician Assistant Program, Boston, MA

- Didactic faculty; promotions committee chair; direct all aspects of interprofessional education curriculum

Assistant Professor of Public Health & Community Medicine, 2021 – 2023
Tufts University School of Medicine Physician Assistant Program, Boston, MA

Site Director / Assistant Professor, 2020 – 2021
University of Utah Physician Assistant Program, Saint George, UT
- Led team of 4 faculty and 2 staff, administered operations at distant campus educating 24 students per class

Assistant Professor, 2018 – 2020
University of Utah Physician Assistant Program, Saint George, UT
- Didactic team faculty at distant campus

Instructor, 2016 –2017
Geisel School of Medicine at Dartmouth College, Hanover, NH
- Involved with anesthesia resident education during perioperative rotation

CLINICAL EXPERIENCE

Physician Assistant, 2021 – 2022
Monadnock Community Hospital Emergency Department, Peterborough, NH
(Part-time)
- Full-spectrum emergency medicine practice at Critical Access Hospital

Physician Assistant, 2020 – 2021
Intermountain St. George Regional Hospital, Saint George, UT
(Part-time)
- Emergency medicine practice at Level II trauma center

Physician Assistant / Advanced Practice Clinician Coordinator, 2017 – 2018
Monadnock Community Hospital Emergency Department, Peterborough, NH
- Full-spectrum emergency medicine practice at Critical Access Hospital
- Coordinate advanced practice provider scheduling for department

Physician Assistant, 2016 – 2017
Dartmouth-Hitchcock Medical Center, Lebanon, NH
- Pre-anesthesia evaluations at Pre-admission Testing Clinic

Physician Assistant, 2014 –2016
Olympic Medical Center Emergency Department, Port Angeles, WA
- Emergency medicine practice at Level III trauma center in rural Washington

Physician Assistant, 2013 – 2014
Quileute Health Clinic, La Push, WA
- Autonomous family medicine practice at remote IHS site

Physician Assistant, 2013
Family Medicine of Port Angeles, Port Angeles, WA
- Family medicine practice in HPSA in rural Washington

SCHOLASTIC HONORS

Article of the Year Award Nominee, Physician Assistant Education Association, 2025
- Peer-nominated for this national award for my article "Gender Disparities in Physician Assistant Educator Promotion and Compensation: A Mixed Methods Approach"

Didactic Faculty of the Year Award, Tufts University School of Medicine PA Program, 2024
- Chosen by students for excellence in teaching during didactic year

Rising Star Award Nominee, Physician Assistant Education Association, 2024
- Nominated by peers for this national award given to an early career PA educator who has made noteworthy contributions to PA education

David J. Keahey Core Faculty Teacher of the Year Award, University of Utah PA Program, 2019
- Chosen by students to receive this award two consecutive years

Outstanding Health Partner, Root For Kids, 2019
- Accepted on behalf of University of Utah PA Program

Pi Alpha, the National Honor Society for Physician Assistants, Inducted 2013

AmeriCorps Scholar in Service, Lock Haven University, 2011 - 2012
- Responsibilities included organization and implementation of community outreach activities within the underserved areas of the central Pennsylvania region

PROFESSIONAL MEMBERSHIPS

Association of Physician Assistants in Cardiology, Member, 2024 – Present
Physician Assistant Education Association, Member, 2018 – Present

SPECIALIZED TRAININGS

- **Learning by Doing: Experiential Teaching Workshop**, 60-minute workshop offered through Center for the Enhancement of Learning and Teaching, Tufts University, September 2025

- **Social Media Marketing**, 45-minute workshop offered through Office of Communications, Tufts University School of Medicine, May 2025

- **Neurodiversity in the Context of College Teaching and Learning**, 2-hour workshop offered through Center for the Enhancement of Learning and Teaching, Tufts University, October 2023

- **Equity and Inclusion Fellows Program,** 1 semester course offered through Center for the Enhancement of Learning and Teaching, Tufts University, Spring 2022

- **Historical Racism in Higher Education**, 9-hour course offered through Center for the Enhancement of Learning and Teaching, Tufts University, January 2022

- **Rethinking your Syllabus – Creating an Inclusive, Equitable, and Anti-racist Syllabus**, 4-hour course offered through Center for the Enhancement of Learning and Teaching, Tufts University, August 2021

- **Faculty Skills 101 Workshop,** 3-day course offered by Physician Assistant Education Association, April 2019

PROFESSIONAL COMMUNITY ACTIVITIES

Physician Assistant Volunteer, 2019 – 2021
Doctors' Volunteer Clinic, Saint George, UT
- Walk-in urgent care services one afternoon weekly in volunteer free clinic

Committee Member, 2019 – 2021
Root For Kids Health Services Advisory Committee, Saint George, UT
- Serve as member of advisory group to local Early Head Start program

Physician Assistant Volunteer, 2019 – 2021
Root For Kids, Saint George, UT
- Precept PA students at health and dental fairs, providing care to children and families, 5-8 times yearly

UNIVERSITY COMMUNITY ACTIVITIES

TUFTS UNIVERSITY SERVICE

SCHOOL OF MEDICINE LEVEL

- Tufts University School of Medicine, Revolutionizing Medical Education Working Group, Member, 2025 – Present

- Tufts University School of Medicine, Bylaws Revision Committee, Member 2024 – Present
- Tufts University School of Medicine, Antiracism Committee, Member 2022 – 2023
- Tufts University School of Medicine, Interprofessional Education Steering Committee, Member 2021 – 2022

PUBLIC HEALTH AND COMMUNITY MEDICINE DEPARTMENT LEVEL

- PHPD, Academic Promotions and Ethics Committee, Member 2022 – 2023

PROGRAM LEVEL

- Tufts University PA Program, Academic Promotions Committee, **Chair** 2022 – Present
- Tufts University PA Program, Core Faculty Search Committee (ad hoc), **Chair**, 2022
- Tufts University PA Program, Curriculum Committee, Member and Subcommittee Lead, 2021 – Present
- Tufts University PA Program, Remediation Committee, Member, 2022 – Present
- Tufts University PA Program, Admissions Committee, Member, 2021 – Present

UNIVERSITY OF UTAH SERVICE

HEALTH SCIENCES LEVEL

- University of Utah School of Medicine, Admissions Sub-committee (SVI), Member, 2019 – 2021

DEPARTMENT LEVEL

- COVID-19 Leadership Huddle, Member, 2020 – 2021

DIVISION LEVEL

- University of Utah PA Program, Didactic Faculty Search Committee, **Chair,** 2020
- University of Utah PA Program, Program Leadership Committee, Member, 2020 – 2021
- University of Utah PA Program, Division Leadership Committee, Member, 2020 – 2021

- University of Utah PA Program, Master's Project Committee, Member, 2019 – 2021
- University of Utah PA Program, Admissions Committee, Member, 2019 – 2021
- University of Utah PA Program, Equity Diversity and Inclusion Committee, Member, 2019 – 2020
- University of Utah PA Program, Pharmacy Faculty Search Committee, **Chair,** 2019
- University of Utah PA Program, International Rotation Committee, Member 2018 – 2021
- University of Utah PA Program, Student Progress Committee, Member, 2018 – 2021
- University of Utah PA Program, Academic Standards and Conduct Committee, Member, 2018 – 2021
- University of Utah PA Program, Didactic Curriculum Committee, Member, 2018 – 2019

SERVICE AT OUTSIDE INSTITUTIONS

- Dixie State University College of Health Sciences, IPE Committee, Member 2020 – 2021

NATIONAL SERVICE

- Journal of Physician Assistant Education, Feature Editor, 2023 – Present
  - "Exploring Medicine Through the Arts"
- Physician Assistant Education Association, Annual Forum Submission Reviewer, 2023 – Present
- Journal of Physician Assistant Education, Reviewer, 2022 – Present

TEACHING RESPONSIBILITIES/ASSIGNMENTS

COURSES DIRECTED:

Summer 2025

PA 204 Internal Medicine II Course, Tufts University PA Program, 50 students, 4 credits

- Course broken into 3 modules (cardiology, pulmonology, endocrinology) with topics involving epidemiology, pathophysiology, clinical presentation, diagnosis, and medical management of commonly encountered conditions in internal medicine.

Spring 2025

PA 203 Internal Medicine I Course, Tufts University PA Program, 50 students, 4 credits

- Course broken into 3 modules (immunology, hematology, infectious disease) with topics involving epidemiology, pathophysiology, clinical presentation, diagnosis, and medical management of commonly encountered conditions in internal medicine.

Fall 2024

PA 220 Evidence Based Medicine Course, Tufts University PA Program, 50 students, 1 credit

- Course provides an overview of the evidence-based medicine process including asking a clinical question, effective literature search methods and resources, critical article appraisal, and application of biomedical research in clinical practice.

PA 226 Clinical Reasoning Workshop, Tufts University PA Program, 50 students, 1 credit

- This workshop based course provides learners opportunities to metacognitively engage in the clinical reasoning process through a series of small group clinical case sessions.

Summer 2024

PA 204 Internal Medicine II Course, Tufts University PA Program, 50 students, 4 credits

- Course broken into 3 modules (cardiology, pulmonology, endocrinology) with topics involving epidemiology, pathophysiology, clinical presentation, diagnosis, and medical management of commonly encountered conditions in internal medicine.

Spring 2024

PA 203 Internal Medicine I Course, Tufts University PA Program, 50 students, 4 credits

- Course broken into 3 modules (immunology, hematology, infectious disease) with topics involving epidemiology, pathophysiology, clinical presentation, diagnosis, and medical management of commonly encountered conditions in internal medicine.

Summer 2023

PA 204 Internal Medicine II Course, Tufts University PA Program, 49 students, 4 credits

- Course broken into 3 modules (cardiology, pulmonology, endocrinology) with topics involving epidemiology, pathophysiology,

clinical presentation, diagnosis, and medical management of commonly encountered conditions in internal medicine.

Summer 2022

PA 204 Internal Medicine II Course, Tufts University PA Program, 49 students, 4 credits

- Course broken into 3 modules (cardiology, pulmonology, endocrinology) with topics involving epidemiology, pathophysiology, clinical presentation, diagnosis, and medical management of commonly encountered conditions in internal medicine.

Spring 2022

PA 203 Internal Medicine I Course, Tufts University PA Program, 50 students, 4 credits

- Course broken into 3 modules (immunology, infectious disease, hematology) with topics involving epidemiology, pathophysiology, clinical presentation, diagnosis, and medical management of commonly encountered conditions in internal medicine.

Fall 2021

PA 205 Internal Medicine III Course, Tufts University PA Program, 50 students, 4 credits

- Course broken into 3 modules (infectious disease, pulmonology, rheumatology) with topics involving epidemiology, pathophysiology, clinical presentation, diagnosis, and medical management of commonly encountered conditions in internal medicine

Spring 2021

PAS 6160 Neurology Course, University of Utah PA Program, 68 students, 2 credits

- Course topics include epidemiology, pathophysiology, clinical presentation, diagnosis, and medical management of commonly encountered neurological conditions. Adapted to fully online, synchronous delivery due to COVID-19 pandemic.

Fall 2020

- PAS 6115 Cardiovascular Medicine Course, University of Utah PA Program, 68 students, 3 credits
  - Course topics include epidemiology, pathophysiology, clinical presentation, diagnosis, and medical management of commonly encountered medical conditions affecting the cardiovascular system. Adapted to hy-flex format due to COVID-19 pandemic.

Summer 2020

- PAS 6240 Inpatient Medicine – Emergency Medicine course, University of Utah PA Program, 64 students, 2 credits

- Introduces students to aspects of medicine carried out in the ED. Students study the epidemiology, pathophysiology, clinical presentation, diagnosis, and management of emergent conditions and are taught skills pertinent to practice in the ED. Adapted to fully online, synchronous delivery due to COVID-19 pandemic.

Spring 2020

PAS 6160 Neurology Course, University of Utah PA Program, 64 students, 2 credits

- Course topics include epidemiology, pathophysiology, clinical presentation, diagnosis, and medical management of commonly encountered neurological conditions. Adapted to fully online, synchronous delivery due to COVID-19 pandemic.

Summer 2019

- PAS 6303 Inpatient Medicine – Emergency Medicine course, University of Utah PA Program, 60 students, 2 credits
  - Introduces students to aspects of medicine carried out in the ED. Students study the epidemiology, pathophysiology, clinical presentation, diagnosis, and management of emergent conditions and are taught skills pertinent to practice in the ED.

Spring 2019

PAS 6202 Clinical Medicine II - Neurology course, University of Utah PA Program, 60 students, 2 credits

- Course topics include epidemiology, pathophysiology, clinical presentation, diagnosis, and medical management of commonly encountered neurological conditions. Incorporates distance learning.

COURSE LECTURES:

Summer 2025

- PA 204 Internal Medicine II Course, Tufts University PA Program, 50 students, 4 credits
  - Primary cardiology, pulmonology module instructor (36 hours)
- PA 229 Diagnostic Imaging Course, Tufts University PA Program, 50 students, 1 credit
  - Presented lecture *Thorax Imaging* (2 hours)

Spring 2025

- PA 290 Preparation for Clinical Practice, Tufts University PA Program, 50 students, 6 credits
  - Presented lectures *Cardiovascular Board Review 1 and 2, Renal Board Review, Hematology Board Review* (8 hours)

- PA 203 Internal Medicine I Course, Tufts University PA Program, 50 students, 4 credits
    - Primary hematology instructor (14 hours)

Fall 2024

- PA 220 Evidence Based Medicine Course, Tufts University PA Program, 50 students, 1 credit
    - Primary instructor (12 hours)

- PA 226 Clinical Reasoning Workshop, Tufts University PA Program, 50 students, 1 credit
    - Presented introductory lecture and led 2 case workshops (6 hours)

Summer 2024

- PA 204 Internal Medicine II Course, Tufts University PA Program, 50 students, 4 credits
    - Primary cardiology, pulmonology module instructor (36 hours)

Spring 2024

- PA 290 Preparation for Clinical Practice, Tufts University PA Program, 50 students, 6 credits
    - Presented lectures *Cardiovascular Board Review 1 and 2, Renal Board Review* (6 hours)

- PA 203 Internal Medicine I Course, Tufts University PA Program, 50 students, 4 credits
    - Primary hematology instructor (14 hours)

Summer 2023

- PA 204 Internal Medicine II Course, Tufts University PA Program, 49 students, 4 credits
    - Primary cardiology, pulmonology module instructor (36 hours)

Spring 2023

- PA 290 Preparation for Clinical Practice, Tufts University PA Program, 50 students, 6 credits
    - Presented lectures *Cardiovascular Board Review 1 and 2* (4 hours)

- PA 203 Internal Medicine I Course, Tufts University PA Program, 50 students, 4 credits
    - Hematology guest lecturer (2 hours)

Summer 2022

- PA 204 Internal Medicine II Course, Tufts University PA Program, 49 students, 4 credits

- Primary cardiology, pulmonology module instructor (36 hours)

- PA 216 Physical Diagnosis II Course, Tufts University PA Program, 49 students, 4 credits
  - Arterial blood gas, Pulmonology exam lectures (5 hours)

Spring 2022
- PA 203 Internal Medicine I Course, Tufts University PA Program, 50 students, 4 credits
  - Primary hematology module instructor (18 hours)

Fall 2021
- PA 205 Internal Medicine III Course, Tufts University PA Program, 50 students, 4 credits
  - Primary pulmonology module instructor (18 hours)

Fall 2020
- PAS 6115 Cardiovascular Medicine Course, University of Utah PA Program, 68 students, 3 credits
  - Presented lecture *EKG Basics* (4 hours)

Summer 2020
- PAS 6240 Inpatient Medicine – Emergency Medicine course, University of Utah PA Program, 64 students, 2 credits
  - Primary course instructor

- PAS 6220 Musculoskeletal Medicine, University of Utah PA Program, 64 students, 2 credits
  - Presented lecture *Introduction to Orthopedic Xrays (2 hours)*

- PAS 6060 Infectious Disease course, University of Utah PA Program, 68 students, 3 credits
  - Presented lecture *Spirochetes and Parasites* (2 hours)

Fall 2019
- PAS 6115 Cardiovascular Medicine course, University of Utah PA program, 64 students, 3 credits
  - Presented lectures *EKG Basics* (3 hours), *Conduction Disorders* (9 hours), *Cardiogenic Shock* (2 hours)

Summer 2019
- PAS 6303 Inpatient Medicine – Emergency Medicine course, University of Utah PA Program, 60 students, 2 credits
  - Primary course instructor

- PAS 6060 Infectious Disease course, University of Utah PA Program, 64 students, 3 credits
    - Presented lecture *Spirochetes and Parasites* (2 hours)

CLINICAL TEACHING:

2019 – 2021: University of Utah PA Program

- Clinical preceptor for medical, PA, and nurse practitioner students at Doctors' Volunteer Clinic in St. George, UT, one 3-hour shift per week. Supervise and teach students during their primary care/urgent care rotation.

2016 – 2017: Geisel School of Medicine at Dartmouth College

- Clinical instructor for anesthesia interns and residents on perioperative rotation on service in Pre-Admission Testing Clinic

SMALL GROUP/PROCEDURAL/SKILLS TEACHING:

Summer 2025

- PA 229 Diagnostic Imaging, Thorax Imaging Workshop Facilitator, Tufts University PA Program
- PA 216 Physical Diagnosis II, Practical evaluator, Tufts University PA Program
- PA 236 Primary Care II, Simulated Patient Encounter, Instructor/Facilitator, Tufts University PA Program

Spring 2025

- PA 201 Clinical Anatomy 1, Thoracic Surface Anatomy & Pneumothorax Cadaver Station, Tufts University PA Program
- PA 215 Physical Diagnosis I, Small Group Teaching, Instructor, Tufts University PA Program
- PA 235 Primary Care I, Simulated Patient Encounter, Instructor/Facilitator, Tufts University PA Program

Fall 2024

- PA 237 Primary Care III, Simulated Patient Encounter, Instructor/Facilitator, Tufts University PA Program
- PA 290 Preparation for Clinical Practice, Summative OSCEs, Evaluator, Tufts University PA Program

Summer 2024

- PA 216 Physical Diagnosis II, Small Group Teaching, Instructor, Tufts University PA Program
- PA 236 Primary Care II, Simulated Patient Encounter, Instructor/Facilitator, Tufts University PA Program

Spring 2024

- PA 215 Physical Diagnosis I, Small Group Teaching, Instructor, Tufts University PA Program
- PA 235 Primary Care I, Simulated Patient Encounter, Instructor/Facilitator, Tufts University PA Program

Fall 2023

- PA 240 Procedural Workshop, Procedural Skills Teaching, Instructor, Tufts University PA Program
- PA 237 Primary Care III, Simulated Patient Encounter, Instructor/Facilitator, Tufts University PA Program
- PA 290 Preparation for Clinical Practice, Summative OSCEs, Evaluator, Tufts University PA Program

Summer 2023

- PA 216 Physical Diagnosis II, Small Group Teaching, Instructor, Tufts University PA Program
- PA 236 Primary Care II, Simulated Patient Encounter, Instructor/Facilitator, Tufts University PA Program

Spring 2023

- PA 215 Physical Diagnosis I, Small Group Teaching, Instructor, Tufts University PA Program

Fall 2022

- PA 237 Primary Care III, Small Group Case Discussion (topic: a. fib), Instructor, Tufts University PA Program
- PA 237 Primary Care III, Simulated Patient Encounter, Instructor/Facilitator, Tufts University PA Program
- PA 290 Preparation for Clinical Practice, Summative OSCEs, Evaluator, Tufts University PA Program

Summer 2022

- PA 216 Physical Diagnosis II, Small Group Teaching, Instructor, Tufts University PA Program
- PA 236 Primary Care II, Simulated Patient Encounter, Instructor/Facilitator, Tufts University PA Program

Spring 2022

- PA 215 Physical Diagnosis I, Small Group Teaching, Instructor, Tufts University PA Program
- PA 235 Primary Care I, Simulated Patient Encounter, Instructor/Facilitator, Tufts University PA Program

Fall 2021

- PA 237 Primary Care III, Small Group Case Discussion (topic: a. fib), Instructor, Tufts University PA Program
- PA 237 Primary Care III, Simulated Patient Encounter, Instructor/Facilitator, Tufts University PA Program
- PA 290 Preparation for Clinical Practice, Summative OSCEs, Evaluator, Tufts University PA Program

Summer 2021

- PA 216 Physical Diagnosis II, Small Group Teaching, Instructor, Tufts University PA Program
- PA 236 Primary Care II, Simulated Patient Encounter, Instructor/Facilitator, Tufts University PA Program

Spring 2021

- PAS 6141 Patient Problem Management II – Tutorial course, Small Group Teaching, Documentation/Oral presentation/Case review instructor, 4 students, 3 hours weekly, semester-long course, Univ. of Utah PA Program
- PAS 6200 Mission in Practice III, Small Group Teaching, Instructor, Univ. of Utah PA Program
- PAS 6150 Hematology/Oncology, Article Dissection Facilitator, Univ. of Utah PA Program

Fall 2020

- PAS 6140 Patient Problem Management I – Tutorial course, Small Group Teaching, Physical Exam skills instructor, 4 students, 3 hours weekly, semester-long course, Univ. of Utah PA Program
- PAS 6100 Mission in Practice 2, Small Group Teaching, Instructor, Univ. of Utah PA Program

Summer 2020

- PAS 6004 Inpatient Medicine – Hospital Medicine course, Simulated Case Facilitator, 3 cases, 4 groups of 5-6 students per case, Univ. of Utah PA Program
- PAS 6971 Master's Project, Virtual Poster Session Grader, Univ. of Utah PA Program
- Pre-clinical bootcamp – Facilitator for fit mask testing and suturing labs, Univ. of Utah PA Program

Spring 2020

- PAS 6141 Patient Problem Management II – Tutorial course, Small Group Teaching, Documentation/Oral presentation/Case review instructor, 4 students, 3 hours weekly, semester-long course, Univ. of Utah PA Program
- PAS 6200 Mission in Practice III, Small Group Teaching, Instructor, Univ. of Utah PA Program

- PAS 6204 Psychiatry Course, Lab Facilitator, Univ. of Utah PA Program

Fall 2019
- PAS 6140 Patient Problem Management I – Tutorial course, Small Group Teaching, Physical Exam skills instructor, 4 students, 3 hours weekly, semester-long course, Univ. of Utah PA Program
- PAS 6090 Pediatrics, Lab facilitator and OSCE evaluator, Univ. of Utah PA Program

Summer 2019
- PAS 6007 Dermatology, Lab Facilitator, Univ. of Utah PA Program
- PAS 6304 Musculoskeletal Medicine, Splinting/Casting Lab Facilitator, Univ. of Utah PA Program
- PAS 6303 Inpatient Medicine – Emergency Medicine course, Univ. of Utah PA Program, Suturing lab facilitator
- PAS 6004 Inpatient Medicine – Hospital Medicine course, Standardized Patient lab facilitator, Univ. of Utah PA Program
- PAS 6971 Master's Project, Poster Session Grader, Univ. of Utah PA Program
- PAS 6300 Mission in Practice 4, Small Group Teaching, Instructor, Univ. of Utah PA Program
- PAS 6050, Medical Interviewing, Small Group Teaching, Instructor, Univ. of Utah PA Program
- Pre-clinical bootcamp – Facilitator for shoulder injection and suturing labs, Univ. of Utah PA Program

Spring 2019
- PAS 6200 Mission in Practice III, Small Group Teaching, Instructor, Univ. of Utah PA Program
- PAS 6202 Clinical Medicine II – Hematology/Oncology course, Small Group Teaching, Instructor, Univ. of Utah PA Program
- PAS 6204 Topics in Medicine I – Psychiatry course, Lab Facilitator, Univ. of Utah PA Program
- PAS 6801 Patient Problem Management II – Tutorial course, Small Group Teaching, Substitute Instructor, Univ. of Utah PA Program

Fall 2018
- PAS 6104 Cardiovascular Medicine, facilitated EKG station during CV lab, Univ. of Utah PA Program

INTERPROFESSIONAL TEACHING:

Ongoing, Year-round (2023 – Present)
- PAS 290 Preparation for Clinical Practice, Tufts University PA Program, 50 students, 6 credits

- Faculty facilitator for 2nd year Tufts University PA students, simulated patient IPE activity (motivational interviewing, nutrition, cultural humility themes) with Tufts MD students and faculty, taught 7 times annually

Fall 2024

- PA 231 Physical Medicine and Rehabilitation, Tufts University PA Program, 50 students, 2 credits
    - Created and presented 3-hour IPE workshop with Tufts OT faculty and students (85 students total) centered around pediatric disability clinical cases
- PAS 290 Preparation for Clinical Practice, Tufts University PA Program, 48 students, 6 credits
    - Created, organized, and implemented 1-day standardized patient simulation activity for clinical year PA students and social workers involving communicating difficult news and end of life care

Spring 2024

- PAS 290 Preparation for Clinical Practice, Tufts University PA Program, 50 students, 6 credits
    - Directed 1.5 hour IPE clinical case workshop with Tufts DPT Boston students (130 students total) focusing on cardiopulmonary patient care

Fall 2023

- PA 231 Physical Medicine and Rehabilitation, Tufts University PA Program, 49 students, 2 credits
    - Created and presented 3-hour IPE workshop with Tufts OT faculty and students (85 students total) centered around pediatric disability clinical cases
- PAS 290 Preparation for Clinical Practice, Tufts University PA Program, 48 students, 6 credits
    - Created, organized, and implemented 1-day standardized patient simulation activity for clinical year PA students and social workers involving communicating difficult news and end of life care

Fall 2022

- PA 231 Physical and Occupational Medicine, Tufts University PA Program, 50 students
    - Created and presented 2 hour IPE clinical case workshop with Tufts DPT Boston students (130 students total) focusing on cardiopulmonary patient care
- PAS 290 Preparation for Clinical Practice, Tufts University PA Program, 48 students, 6 credits

- Clinical Skills Interclerkship, Interprofessional Simulation Rotation (topic: palliative, end of life care, pain management), Instructor, Tufts University PA Program, TUSM, MCPHS Pharmacy Program, Simmons University Social Work Program

Spring 2022

- PAS 290 Preparation for Clinical Practice, Tufts University PA Program, 50 students, 6 credits
    - *Collaborative Approaches to the Management of Nicotine Addiction*, Online Interprofessional Education Rotation.
        - Developed with faculty from Tufts School of Dentistry and Massachusetts College of Pharmacy and Health Sciences Pharmacy and PA programs
        - Facilitated 5, 4-hour sessions with PA, dental, and pharmacy students
- PA 260 Professional Practice, Tufts University PA Program, 50 students, 2 credits
    - Created and presented 1.5 hour IPE workshop with Tufts DPT Boston students (130 students total) highlighting health inequities in the US

Fall 2021

- PAS 290 Preparation for Clinical Practice, Tufts University PA Program, 50 students, 6 credits
    - Clinical Skills Interclerkship, Interprofessional Simulation Rotation (topic: palliative, end of life care, pain management), Instructor, Tufts University PA Program, TUSM, MCPHS Pharmacy Program, Simmons University Social Work Program

2019-2020

- Developed, coordinated, and facilitated IPE experience for Univ. of Utah PA Students and Dixie State Univ. dental hygiene students. Several sessions, year round.
    - Free oral health clinic open to un/underinsured children and their families in the region in conjunction with a local Early Head Start Program (Root For Kids)

INTERNATIONAL TEACHING:

Summer 2019

- Thailand International Elective
    - Accompanied Univ. of Utah students for 2 weeks on hospital rotations in Bangkok and on rotations at Mae Tao Clinic which provides free medical services to displaced Burmese people at Thailand-Burma border

EDUCATIONAL LECTURES:

Spring 2025

- *Using Music in the Health Professions Education Classroom*, 1 hour presentation presented as part of the Tufts University School of Medicine Office of Educational Affairs Faculty Development Webinar series

Spring 2022

- *Physician Assistant: an overview*, asynchronous lecture presented as part of *Introduction to the Dental Patient* course, Tufts University School of Dental Medicine

Fall 2020

- *The Physician Assistant Profession and the University of Utah PA Program*, presented to medical radiography students at Dixie State University

Spring 2019

- *Introduction to SBAR*, presented at Dixie State University Interprofessional Education Event

TRAINEE SUPERVISION

MASTERS:

2025 – 2026

- Advisor/Mentor, Tufts University PA Program capstone project, 8 students
    - Aparicio, D. Initial Antibiotic Therapy versus Delayed Appendectomy: Impact on Post-operative Outcomes.
    - Berg, G. Pelvimetry: Historical Influences on Modern Practice.
    - Farrell, K. The Role of Fasting in Metabolic Syndrome.
    - Jung, K. A Case of Major Depressive Disorder with Psychotic & Catatonic Features Precipitated By Mild TBI.
    - Opoku Twumwaa, E. Barriers to Mental Healthcare for Immigrant Women Affected by Female Genital Cutting.
    - Sammartino, E. A Comparison of Outcomes Between Open and Robotic Pancreaticoduodenectomy.
    - Savage, E. Biologic Therapies in Treatment of Systemic Juvenile Idiopathic Arthritis
    - Zakhari, V. The Role of Platelet Rich Plasma in the Treatment of Rotator Cuff Tears

2024 – 2025

- Advisor/Mentor, Tufts University PA Program capstone project, 6 students
    - Anderson L. Polycystic Ovarian Syndrome.
    - Ardizzoni A. Beyond The Gluten-Free Diet: Additional Treatment Options for Patients with Celiac Disease.
    - Duarte S. Expanding the Landscape of HIV Prevention: A Comprehensive Review of PrEP Options and the Emerging Role of Lenacapavir.
    - Johnson A. A Guide to Management of Chronic Immune Thrombocytopenic Purpura in Adults.
    - Lawrence M. Comfort in Contraception: An Overview of Pain Relief Options During IUD Insertion.
    - McMurphy K. Infantile Spasms: Cost, Efficacy, and Safety of Two Treatment Options.

2023 – 2024

- Advisor/Mentor, Tufts University PA Program capstone project, 9 students
    - Mahamde S. Improving Health Outcomes in People Who Inject Drugs with Infective Endocarditis.
    - Stead J. Hemiplegic Migraine: The Diagnostic Challenge.
    - Sarlls K. Bridging the Gap in Medical Education: Comprehensive Strategies for Caring for Individuals with Intellectual Disabilities.
    - Heffrin K. Femoroacetabular Impingement Resulting in Labral Tears in Young Athletes.
    - Phinney J. Waking Up with Gluteal Compartment Syndrome: A Case Report.
    - Culver H. Regenerating Meniscus: Stem Cell Therapies and The Future of Meniscus Repair.
    - Patel K. Hidradenitis Suppurativa.
    - Gale B. The Causal Association between Type 1 Diabetes and Gut Dysbiosis: Targeting the Gut Microbiota to Halt Development of and Treat Type 1 Diabetes.
    - O'Rourke R. Looking Beyond Pharmaceuticals: Evaluating the use of device assisted therapies in the treatment of Parkinson's Disease.

2022 – 2023

- Advisor/Mentor, Tufts University PA Program capstone project, 7 students.
    - Block Y. Pancreatic Cancer: an overview of risk, prevention, and screening in 2022.
    - Dodd S. Neurofibromatosis Type 1: A Multidisciplinary Approach to Understanding a Multifaceted Disease.
    - Gerrior C. Cubital Tunnel Syndrome: Which Surgical Technique is Best and Why?
    - Gottlieb D. The Impact of Exercise on Quality of Life in Patients with Diabetic Neuropathy.

- Kelly C. Preventing menstrual cycle-related ACL injuries in females of childbearing age.
- Mikulski M. The Future of ACL Reconstruction: Do Traditional Surgical Repair Techniques or BEAR Implants Provide Better Long Term Outcomes?
- Van Tassel S. Does the Utilization of Point-of-Care Ultrasound in Emergency Medicine Decrease Morbidity and Mortality in Trauma Patients?

2021 – 2022

- Advisor/Mentor, Tufts University PA Program capstone project, 4 students.
  - Moody A. Early Recognition of Child and Adolescent Anxiety: Identification of Appropriate Screening Tools for Pediatric Anxiety.
  - Smith H. Diagnosis, Management and Prevention of Cannabinoid Hyperemesis Syndrome in Emergency Settings.
  - Tromblay D. The Clinician's AFib Anticoagulation Playbook: A Summary Review of Indications and Guidelines for Anticoagulation Management in Patients with Nonvalvular Atrial Fibrillation.
  - Youngberg C. The Role of Convalescent Plasma Donation from Recovered COVID-19 Patients in the Continuing Fight against the Coronavirus Pandemic.

2020-2021

- Advisor/Mentor, Univ. of Utah PA Program, Master's Project, 2 groups, 4 students each
  - Cardenas L, Florence B, Farmer S, Farnsworth K. The Social Determinants of Telehealth – Demographic Effects on a Patient Population at a Free Clinic in St. George, Utah during the COVID-19 Pandemic.
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  - Allen M, DeLong J, Romero M, Vongsawad S. Let's Give It A Shot: Improving Immunization Rates in an Early Head Start Population in St. George, Utah

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- **Loder R.** Review question item writer and reviewer. Risling-DeJong, Hammerbacher (Eds.), *Clinical Reasoning for Physician Assistants: A Workbook for Certification Review and Practice Readiness* (1st). Elsevier. July 2023.

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POSTER PRESENTATIONS:

- Morris M, Whitney R, **Loder R**. Interprofessional Education Delivery for OT and Physician Assistant Students & Outcomes Using the Interprofessional Collaborative Competency Attainment Scale. Poster presented at American Occupational Therapy Association Inspire Conference, Philadelphia, PA, April 2025.

- **Loder R**, Buyea B (October 2023). SPENT: Creating Interprofessional Discussion Through Virtual Poverty Simulation. Poster session presented at Physician Assistant Education Association Annual Forum.

- Washington R, Pathare N, **Loder R** (October 2023). Building Interprofessional Competency Through a Virtual Cardiopulmonary Case

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ORAL PRESENTATIONS:

- Honda T, Dehn R, Barry C, **Loder R**, Coplan B (October 2025). Peer Reviewing for PA Journals. Makerspace workshop presentation at Physician Assistant Education Association Annual Conference, San Diego, CA.

- Dunbar H, **Loder R**. (October 2025). Aiming to Improve Inclusion and Equity in Physician Assistant Education
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- **Loder R**, Bennett R, Murray J, Sunada G (August 2020). *Developing an Oral Health, Interprofessional, Community Engaged Learning Opportunity for Primary Care Trainees.* Accepted as a scholarly roundtable discussion, switched to narrated slide presentation due to COVID-19 pandemic.

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Abstract

Title of Dissertation: The Effect of Song-based Instruction on First-Year Physician Assistant Students' Knowledge Acquisition

Rayne Loder, Doctor of Philosophy, 2025

Dissertation Directed by: Violet Kulo, EdD, PhD, Associate Professor, School of Graduate Studies, University of Maryland Baltimore

The purpose of this embedded mixed-methods study was to a) determine whether song-based instruction effects foundational hematology knowledge acquisition as measured by hematology module summative exam scores for first-year physician assistant (PA) students and to b) explore student perceptions of song-based instruction on their medical knowledge acquisition. Information processing theory was used to understand mechanisms by which the song-based intervention might impact learning. The study included a sample of 100 first-year PA students enrolled in a foundational hematology module, 50 of whom received lecture-based instruction only, and 50 of whom received instruction which included the use of songs with content-specific lyrics. In the quantitative component of this study, a quasi-experimental, posttest only design was employed to evaluate for differences in assessment scores between cohorts. Quantitative subanalyses were performed to further evaluate the impact of the song-based intervention on assessment performance, including the impacts of familiar melody and musical experience. In the qualitative component of the study, interviews were conducted with students in the experimental cohort and data underwent thematic analysis to explore student perceptions of the song-based intervention. The quantitative analysis showed that there was no statistically significant difference (p = .400) in hematology module exam

scores between the control (M = 95.36, SD = 3.713) and experimental (M = 96.00, SD = 3.854) cohorts. Quantitative subanalyses similarly resulted in no statistically significant differences in exam scores in the experimental cohort for test items covered in songs versus items not (p = .219), items taught by songs with familiar versus novel melodies (p = .894), and within the cohort based on musical ability (p = .811). Qualitative analysis resulted in three themes (Songs supported knowledge acquisition in multiple ways, Songs positively impacted the learning experience, and Songs facilitated reflection and connection) which suggested positive effects of the intervention that were not measured quantitatively. The findings from this study suggest that a song-based instructional approach has the potential to be an engaging, joyful, and impactful intervention to support the acquisition of foundational knowledge in health professions learners.

The Effect of Song-based Instruction on First-Year Physician Assistant Students' Knowledge Acquisition

by
Rayne Loder

Dissertation proposal submitted to the Faculty of the School of Graduate Studies of the University of Maryland, Baltimore in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
2025

Dedication

To Scott, Charlotte, and Henry for granting me the space to complete this degree, and for loving and supporting me always

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CHAPTER 1: INTRODUCTION

Background

Songs have been used since ancient times as a medium for the enduring transfer of verbal information from person to person. For example, many of the heroic Greek stories in the Odyssey are presented as songs performed by poets (Biles, 2003). Song has been, and continues to be, an important tool in the transmission and preservation of oral histories around the world, including within Irish (Cassidy, 2022), Kenyan (Muhoro, 2002), Chinese (Schaberg, 1999), and American (Dzuris, 2003) cultures. This utilization of song throughout human history to share and preserve information suggests its effectiveness as a tool for communication and retention of knowledge.

There are examples of song being used as a tool for communication and retention of information in educational contexts as well. The most familiar example of this may be in early childhood education where foundational knowledge (letters, colors, shapes) is commonly taught through songs and nursery rhymes. There is a rich body of evidence in the psychology and language-learning literatures which supports that song is a valid tool to support acquisition of this type of foundational knowledge not just for children, but in adult educational contexts as well (Chazin & Neuschatz, 1990; Ginsborg & Sloboda, 2007; Li & Brand, 2009).

It is plausible that song-based instructional techniques can add value to many types of curricula, especially in early phases of learning during which the educational focus is typically on the acquisition of foundational knowledge. The literature contains reports of songs being incorporated into undergraduate and graduate-level Science, Technology, Engineering, and Mathematics (STEM) instruction to aid learners in the

acquisition of foundational knowledge in these disciplines. For example, McLachlin (2009) described using a song with content-specific lyrics in a large biochemistry lecture hall while Dickson and Grant (2003) composed songs consisting of content-specific song lyrics to help undergraduate students better remember basic physics concepts.

Within the field of health professions education, which falls under the umbrella of STEM, there have been only a few accounts in the literature of a song-based instructional approach being employed, and primarily within the field of nursing. For instance, Hermanns et al. (2012) used novel songs to help nursing students learn psychopharmacologic concepts with anecdotally positive student reactions to the intervention. Chan (2014) described flipping the song-writing task to nursing students by asking the students to compose new songs about epilepsy and found that students perceived the activity to have positively impacted their learning and problem-solving, helped with the memorization of the educational content, and generally made learning more engaging.

Physician Assistant Education

The physician assistant (PA) profession is one health profession discipline which has the potential to benefit from song-based instructional techniques. PAs are a type of advanced practice medical provider trained in an accelerated educational model with the intent to have PA graduates extend medical care to locations and populations which have been historically underserved by the medical system. PA programs are, on average, 27-months in duration with the first 12-15 months dedicated to didactic, or classroom-based, instruction (American Academy of Physician Associates, n.d.). The focus during this didactic phase of education is on the acquisition of foundational medical knowledge

which will then be applied to patient care during the clinical training phase of the program (Jones, 2007). PA students must acquire vast amounts of knowledge during the didactic phase of their education, essentially learning the same breadth of information in one year that medical students learn in two years (Hooker et al., 2017).

PA educational programs receive guidance regarding which topics to include in didactic curricula by the content blueprint of the PA National Certification Examination (PANCE). The PANCE is a 300-question standardized multiple-choice examination administered by the National Commission on the Certification of the Physician Assistant (NCCPA) which assesses the knowledge, skills, and behaviors expected of entry-level PAs (National Commission on Certification of Physician Assistants, n.d.-a). The PANCE must be passed by graduates of PA programs to become nationally certified PAs who are eligible for state licensure.

To help assess progress toward attainment of entry-level knowledge, the Physician Assistant Education Association (PAEA) produces and makes available a variety of standardized medical knowledge examinations for utilization by PA educational programs. The PA Clinical Knowledge Rating and Assessment Tool (PACKRAT), a 225-question standardized multiple-choice examination whose content mirrors the PANCE, is first administered by over 95% of PA programs near the end of the didactic phase of a PA program and is intended as a student self-assessment of medical knowledge (Physician Assistant Education Association, n.d.). PAEA also produces seven End of Rotation (EOR) examinations which are administered following completion of core PA clinical rotations (e.g., internal medicine, general surgery,

pediatrics) and which each contain 120 multiple-choice questions covering high yield topics relevant to each rotation (Physician Assistant Education Association, 2023).

Five percent of PANCE questions (National Commission on Certification of Physician Assistants, n.d.-b), 3% of PACKRAT questions (Physician Assistant Education Association, 2018), and 5% of internal medicine EOR examination questions (Physician Assistant Education Association, 2023) directly pertain to diseases and disorders of the hematologic system. Hematology, the study of blood disorders, is a field of great clinical relevance which includes both benign and malignant conditions and which overlaps with disorders of other areas of medical study, including oncology (Mandan et al., 2016). PA students are expected to possess an understanding of common hematologic topics at the conclusion of the didactic phase of their training. However, the national average exam scores for hematology content on a recent version of the PACKRAT administered to first year PA students was 45%, the second lowest average score across all content areas on the exam (Physician Assistant Education Association, 2024c). Likewise, mean scores on the hematology section of the internal medicine EOR examination for graduating classes of 2024 and 2025 (mean score of 410 both years) were below the overall mean exam score (mean score of 414 both years) (Physician Assistant Education Association, 2024b). These findings suggest there is an opportunity for improved teaching and learning of foundational hematology within PA education.

At the beginning of this decade, the PAEA Presidents Commission issued a challenge to PA educators to "focus on innovation and 'thinking outside the box'" to support learning in ways which are engaging and effective and to subsequently conduct research which evaluates the outcomes of curricular innovations (Hills et al., 2020, p.

126). While there is robust evidence for the efficacy of learning foundational discipline specific knowledge through song (particularly memorization-based content), there have been no previous studies which explore the impact of song-based instruction, an instructional method which may be considered both innovative and outside-the-box, within the field of PA education. Given the relative underperformance of PA students in hematology based on recent national assessment data (Physician Assistant Education Association, 2024c, 2024b), integrating an outside-the-box teaching method that might help students process and remember information easily, like song-based instruction, is worthwhile of exploration and could have applications to other content areas beyond hematology.

Theoretical Context

Information processing theory was developed by George Miller in the 1950s to explain how humans construct information in their minds, drawing comparisons between human information processing and computer information processing (Miller, 1956). Atkinson and Shiffrin (1968) further developed Miller's original information processing theory by developing "the three-stage information processing model" which describes that information is processed first in the sensory register, then in short-term memory, and finally in long-term memory.

Within information processing theory, encoding is the process by which information is stored, or retained, and integrated with existing information in the long-term memory. Encoded information can be elaborated, or connected to, pre-existing information and organized into groups with similar information (Ashcraft & Radvansky, 2014; Atkinson & Shiffrin, 1968; Miller, 1956). Individuals can then retrieve, or access, information stored in the long-term memory. "Encoding-retrieval similarity" is a concept

which proposes that information which is encoded together (such as the lyrics and melody of a song) will be later most effectively retrieved together (Baddeley, 1997). Similarly, providing "retrieval cues" which were present at the time of encoding can help to retrieve information (Schunk, 2020).

Information processing theory (Atkinson & Shiffrin, 1968; Miller, 1956) is relevant to this study because it offers mechanisms to explain how song-based instructional methods may impact learning. When learning a song, both the melody and the lyrics are encoded together. The work of Chazin and Neuschatz (1990) provides evidence to suggest that the melody of a song later functions as the retrieval cue for the verbal information tied to its lyrics. This has been supported by the findings of Wallace (1994), who found that a song's melody acts as a mnemonic for its lyrics, McElhinney and Annett (1996), who found that song-based learning results in significantly better recall of information, and Ginsborg and Sloboda (2007), who found that words learned as lyrics to a melody are later recalled more accurately than when words and melody are learned separately. Though these studies seem to offer a connection between the theory of information processing and positive impacts of song-based instructional methods, they come from the psychology literature. There has not yet been a study in the health professions education literature which uses information processing theory as a framework to explore the impact of song-based instructional method on knowledge acquisition.

Statement of the Problem

There is a lack of evidence, both quantitative and qualitative, within the PA education literature regarding the effects of song as an instructional tool for foundational knowledge acquisition. This is despite evidence from the psychology literature that

learning information as lyrics tied to a melody results in more complete and accurate recall of that information versus a non-musical presentation (Chazin & Neuschatz, 1990; Ginsborg & Sloboda, 2007). There are examples in second language learning (Li & Brand, 2009), undergraduate STEM education (Dickson & Grant, 2003; McLachlin, 2009), and nursing education (Chan, 2014; Hermanns et al., 2012) on how song is being effectively utilized to facilitate learning, but as of yet there have been no published examples of this within PA education.

Leadership within PA education has recently called for PA faculty members to employ novel and innovative ideas into the PA curricula (Hills et al., 2020) making this an apt time to explore the impact of using a song-based approach to deliver educational content within this field. Hematology is one foundational topic, among many, within PA education which requires a great deal of declarative knowledge acquisition from early learners. Recent results from national assessments of first year PA students demonstrate a lower performance in hematology by exam takers across the US (Physician Assistant Education Association, 2024b, 2024c). This disparity in hematology knowledge within the national PA student population is also reflected within one program in New England in which mean student scores in the hematology section on a recent administration of PACKRAT were lower (38%) than the national mean in this section (45%). A song-based instructional approach to hematology instruction has the potential to address this problem, but as of yet there have been no studies exploring this approach within PA education.

Purpose of the Study

The purpose of this embedded mixed-methods study was to a) determine whether song-based instruction effects foundational hematology knowledge acquisition as measured by hematology module summative exam scores for first-year PA students and to b) explore student perceptions of song-based instruction on their medical knowledge acquisition. The sample in this study was first semester PA students enrolled in a hematology module. For the quantitative portion of the study, the dependent variable was knowledge acquisition as measured by hematology module summative exam scores. The independent variable was instructional method (lecture-only versus inclusion of content-specific songs). For the qualitative portion of the study, interviews were conducted with students who experienced the song-based instructional method.

Significance of the Study

There is a gap in the literature regarding the use of song as an instructional strategy to teach foundational concepts, like hematology, in PA education (and much of health professions education). This gap includes a lack of both quantitative studies which measure the effects of song-based instruction *and* qualitative studies which explore the perceived effects of song on the knowledge acquisition process. The existing studies which have explored impacts of song-based instruction using quantitative methodology are mainly from the psychology literature (Chazin & Neuschatz, 1990; Ginsborg & Sloboda, 2007; Kilgour et al., 2000; Wallace, 1994), not the health professions education literature. Within health professions education, there are only a few studies describing song-based instruction which use qualitative data but without employing robust

qualitative methodology (Chan, 2014; Hermanns et al., 2012). There are no studies at all exploring song-based instruction within PA education.

A great deal of educational research in the PA education field focuses on outcomes related to once innovative but now widely accepted instructional approaches, such as problem-based learning and simulation (Hocking et al., 2013). This study employed rigorous research methodology to both quantitatively and qualitatively evaluate a song-based approach to teaching foundational hematology to PA students. This may open doors for future research into how music and other humanities-based instructional approaches (e.g., visual arts, literature) can be used in PA education, which includes over 300 accredited PA programs in the United States (Accreditation Review Commission on Education for the Physician Assistant, n.d.). This may perhaps also be extrapolated to inform curricular decisions within health professions education in general.

Developing novel, evidence-based educational strategies such as using song to teach foundational medical topics in PA education would benefit PA students and, ultimately, the future patients they will serve. Furthermore, music is a joyful and universal aspect of the human experience; including a qualitative component to this study allowed for analysis of the impacts of the humane aspects of music on learning within the context of health professions education. Developing an effective teaching strategy involving the arts within PA education, such as song-based instruction, could enhance the teaching and learning experience of both instructor and students.

This study also has theoretical significance in relation to its grounding in the theory of information processing (Atkinson & Shiffrin, 1968; Miller, 1956). The quantitative arm of this study explored the impact of song-based instruction on

hematology knowledge acquisition in the sample of PA students studied, contributing to the preexisting literature demonstrating that song provides retrieval cues which aid in information recall (Chazin & Neuschatz, 1990; Ginsborg & Sloboda, 2007; McElhinney & Annett, 1996; Wallace, 1994). The qualitative component added further understanding to the mechanism by which learners perceive that song-based instruction effects acquisition of knowledge.

Research Questions and Hypotheses

The research questions and hypotheses for this study are as follows:

RQ1: Is there a difference in hematology module summative exam scores between first-year PA students who participate in song-based instruction and those who do not?

H_0: There is no difference in hematology module summative exam scores between first-year PA students who participate in song-based instruction and those who do not.

H_A: There is a difference in hematology module summative exam scores between first-year PA students who participate in song-based instruction and those who do not.

RQ2: How do students perceive their acquisition of foundational hematology knowledge through song-based instruction?

Definition of Key Terms

1. *Content-specific lyrics*: Lyrics which describe new information to be learned (McLachlin, 2009)

2. *Encoding*: “Any system that stores information…like human memory…must first of all be able to register the information, a process known as encoding” (Baddeley, 2014, p. x)
3. *Hematology*: a medical science that deals with the blood and blood-forming organs (Merriam Webster, n.d.-a)
4. *Physician Assistant*: “PAs (physician associates/physician assistants) are licensed clinicians who practice medicine in every specialty and setting. Trusted, rigorously educated and trained healthcare professionals, PAs are dedicated to expanding access to care and transforming health and wellness through patient-centered, team-based medical practice.” (American Academy of Physician Associates, n.d.)
5. *Retrieval*: “Any system that stores information…like human memory…must be able to find and output that information when required, the process of retrieval” (Baddeley, 2014, p. x)
6. *Song*: “A short musical composition of words and music” (Merriam Webster, n.d.-b)

Summary

Songs have been used by people for millennia to aid in the communication and memory of important stories and historical information (Biles, 2003; Cassidy, 2022; Dzuris, 2003; Muhoro, 2002; Schaberg, 1999). There have been experimental studies which show that learning words and music together allow the words to be later recalled with greater accuracy (Ginsborg & Sloboda, 2007; McElhinney & Annett, 1996; Wallace, 1994). There have been some accounts of using songs with content-specific lyrics to

teach foundational knowledge concepts within undergraduate science (Dickson & Grant, 2003; McLachlin, 2009) and nursing education (Chan, 2014; Hermanns et al., 2012), but no such studies have been conducted within the field of PA education. Song-based instruction would plausibly be of benefit within PA education, with its initial didactic emphasis on acquiring foundational declarative knowledge.

Hematology is one foundational topic within PA education which may particularly benefit from a novel approach to instruction based on relatively low scores in this area on a recent national standardized examinations (Physician Assistant Education Association, 2024c, 2024b) and specifically within one New England-based PA program. Information processing theory helps to explain how song facilitates learning through the dual encoding of musical and lyrical information which may provide later recall cues (Atkinson & Shiffrin, 1968; Miller, 1956). To address the lack of research on song-based instruction in PA education and to investigate the efficacy of a song-based approach in teaching hematology, an embedded mixed-methods study was conducted to examine the differences in hematology exam scores between first-year PA students who participate in song-based instruction and those who do not. Student perceptions of how song-based instruction impacts knowledge acquisition was explored. The findings of this study will inform PA educational curricula by adding evidence regarding an educational approach not previously described in the PA educational literature and has the potential to add to the information processing theoretical knowledge base as well.

CHAPTER 2: LITERATURE REVIEW

Introduction

This chapter will present a review and critical appraisal of relevant literature on song-based instruction. First, the psychology literature will be reviewed to show efficacy of song-based instruction and explore possible mechanisms of song as an instructional tool. Next, a review of song-based instructional techniques published in undergraduate STEM and health professions education (HPE) will be presented. An argument will be made for studying song-based instructional strategy in PA education. Lastly, information processing theory and its relevance to the proposed study will be discussed followed by a summary of the chapter.

Related Literature

The following is a synthesis of the literature related to using song as an instructional tool. In this first section, studies from the psychology literature will be presented to establish that there has been a building body of evidence over the past three decades which supports the efficacy of song as a memory tool. This will be followed with a discussion of song-based instruction within STEM and HPE and the need for exploration of song-based instruction within PA education.

Song as a Memory Tool: A Review of the Psychology Literature

There is evidence within the psychology literature for the efficacy of song as a memory tool and hypotheses regarding mechanisms for how song helps to facilitate learning. Chazin and Neuschatz (1990) aimed to establish whether song could function as an effective mnemonic device in both a sample of children (n = 26, 8-year-olds) and young adults (n = 20, 18–21-year-olds). In this experimental study, the authors

endeavored for participants to learn basic facts about minerals, a topic chosen because of its esoteric nature. The authors divided participants into 4 groups based on age and instructional type (song-based vs. lecture-based). The song-based groups learned about minerals through a song (set to the tune of "Mary Had a Little Lamb") and the lecture-based groups learned the same information but in spoken form. Participants were asked to write down anything they recalled from the song or lecture immediately after the session, then again 1 week later.

The authors found that both age groups immediately recalled significantly ($F(1,42) = 4.99$, $p < .05$) more minerals when learned through song ($M = 3.39$, $SD = 2.84$) than when learned through lecture ($M = 2.26$, $SD = 2.70$)). However, the benefit of song-based instruction in recall was not significant (p-value not reported) when retested 1-week after the exposure. The findings of this study suggest that teaching new content in the form of lyrics attached to familiar songs may be an effective technique in children *and* young adult populations, though calls into question whether it is effective for long term retention and recall. The small sample sizes for both experimental groups and lack of transparency into sampling methods in this study limit this study's validity. While this study was conducted more than three decades ago, it is the first to establish that the use of songs in the classroom setting could be tailored for adult learning contexts. It also demonstrated the use of song to learn novel, scientific information akin to the type of information learned by health professions students, though the content of the song lyrics in this case (minerals) was not contextually relevant to the participants (children and non-geologist adults). This study offers early evidence that a song-based teaching approach could have a role within science-oriented HPE classrooms, though further research is

needed to judge external validity of this approach when song content matches educational context.

Three years after Chazin and Neuschatz (1990) demonstrated that song may be an effective tool for short-term recall of scientific information in adult learners, Calvert and Tart (1993) investigated how learning a verbal passage (the preamble to the United States Constitution) through song impacts ability to recall information in short, long-term, and very long-term time frames. The authors used two different study methods to address their research question. In the first method, a naturalistic study was employed to test "very long-term recall" of information, referring to recall of information by adults which was learned through song during childhood.

The authors initially included 16 undergraduate students, 8 men and 8 women. Inclusion criteria and sampling method were not described. Participants were instructed to write down the words of the preamble to the United States Constitution from memory. After completing this task, the students were asked to indicate whether they were familiar with the song "The Preamble", first popularized in the children's educational television show Schoolhouse Rock! approximately 15 years prior to the study, if they sang this song to themselves while completing the writing task, and if they perceived singing to be an effective retrieval strategy. The authors did not report duration of elapsed time between the time of the study and the participants' last exposure to the song or otherwise define "very long-term". Students who used singing to help remember the words ($M = 37.88$, *SD* not reported) recalled statistically significantly more words ($t(14) = 4.50$, $p < .001$) than those who did not ($M = 8.63$, *SD* not reported). Most students (88%, $n = 14$) perceived

the song to be an effective memory tool regardless of whether they employed singing during the task.

To test short and long-term memory impacts from song-based instruction, a second, experimental study was conducted. In this study, 28 undergraduate students who reported *not* being familiar with "The Preamble" song were divided into four groups: a group who listened to "The Preamble" song once, a group who listened to "The Preamble" song repeatedly, a group who listened to a recording of someone reading the preamble (in the same time and rhythm as the song) once, and a group who listened to this spoken recording repeatedly. Participants were asked to write down the words of the preamble immediately following the intervention and again 5 weeks later. The group who heard the preamble repeatedly in song form recalled statistically significantly more ($F(1,24) = 4.58$, $p < .05$) words than other treatments. The superiority of repeated song-based learning persisted at the 5 week point and, in fact, significantly strengthened ($F(1, 24) = 6.94$, $p < .01$).

This study is important as it demonstrates the effectiveness of pairing verbal information (in this case, the words of the preamble) with music as a tool to improve recall of that verbal information both immediately, long-term, and in the very long-term. This contrasts with the findings of Chazin and Neuschatz (1990), who did not find that song helped with long-term recall. Calvert and Tart's (1993) findings are strengthened by their use of a naturalistic method as well as an experimental method with congruent findings in both. However, the sample sizes in both aspects of this study are quite small and the authors do not describe how study participants were recruited; it is unclear whether there may have been bias in the selection process or if participants themselves

were biased toward a positive outcome in the song-based treatments. The lack of specificity regarding duration between exposure and measurement, as well as the lack of definition of the term "very long term", impacts the internal validity of the study. Furthermore, the authors only assessed pure recall of information without any analysis of comprehension or application of information, which is essential within PA education.

Despite these limitations, there is nonetheless evidence here to support the use of song, particularly if presented repetitively, to strengthen recall of verbal material. The finding that song helps with recall of information many years after it was initially presented is particularly valuable within PA education as students will graduate and become healthcare providers who will need to recall foundational information throughout their decades-long careers in medicine. The inclusion of questions regarding student *perceptions* of song as a mnemonic adds breadth to the understanding of the phenomenon and the theoretical mechanism by which the song may impart a learning advantage. However, further research is needed to assess whether song-based instruction allows for application of recalled information to the more complex clinical scenarios which health professions students must learn to navigate. There is also opportunity for further research into the perceived mnemonic effects of song.

Wallace (1994) further demonstrated the efficacy of song as a memory tool in a series of experiments with a sample of undergraduate psychology students. Additionally, Wallace (1994) aimed to better understand which aspects of song assist with retention and recall of information; is it the melody or the rhythm of the song or the poetic presentation of lyrics? In the first experiment, 64 students were divided into two groups and exposed to words presented either in a sung or spoken manner. Students listened to

the words five times and were asked to write down what they remembered immediately after the first, second, and fifth exposures and 20 minutes after the final exposure. Recall for text was significantly superior in the sung condition ($F(1, 60) = 19.95$, $p < .0001$) and recall improved with the number of exposures ($F(2, 120) = 598.96$, $p < .0001$). Superior recall for text in the sung condition persisted at the 20-minute post-exposure time point ($F(1, 63) = 11.77$, $p < .001$) and remained when controlling for musical ability.

In a second experiment to determine whether the rhythm of music is the primary contributor to memory advantage, two groups ($n = 21$) were exposed to words presented either as song or as words read rhythmically with a backing beat. Again, recall was better in the sung treatment immediately after exposure ($F(1, 54) = 5.04$, $p < .03$) indicating that it is more than simple rhythm which contributes to the song advantage. Additional experimental treatments refined understanding of the phenomenon, showing that the song advantage is stronger when using songs with repetitive verses and melodies. Wallace (1994) concluded that the melody itself is what seems to provide mnemonic value and posited that this may be due to the way that information is chunked into units by the framework of the song, making it both easier to retain and recall.

The robust methodology of Wallace's (1994) study adds validity to her results and the multiple experimental treatments add subtlety and refined understanding of the possible mechanism by which song provides learning advantage. These findings complement the findings of Calvert and Tart (1993) by demonstrating the efficacy of song as a memory tool. Showing an enduring advantage to song-based learning when controlling for musical ability indicates the potential broad application of this as an effective tool without the need to be concerned about diverse student musical abilities in

the classroom, which would be expected if applying this learning technique within a HPE setting.

McElhinney and Annett (1996) added to the body of evidence supporting song as a mnemonic device by conducting a mixed-factorial study in which 20 senior psychology students were divided into two groups and asked to learn a verbal passage. Similar to the methods employed by Wallace (1994), one group was exposed to the words as lyrics to a recorded song and the second group listened to a recording of the spoken words. Each group listened to the words three times and were asked to recall words after each exposure. The authors intentionally chose a song which was unknown to the study participants to counterbalance the experiment of Chazin and Neuschatz (1990) in which a familiar tune was chosen. Although there were no statistically significant differences in the learning conditions after the first exposure ($U = 66$, $p > .05$), the song-based condition resulted in significantly better recall after the second ($U = 94.5$, $p < .001$) and third exposures ($U = 92$, $p < .001$), consistent with the findings of Wallace (1994). Song-based learning also resulted in students remembering significantly more information in units, or chunks, related to the framework of the song versus random words, at all three time points ($U = 75.3$, $p < .001$; $U = 72$, $p < .05$; and $U = 74$, $p < .05$, respectively).

The authors suggested that the incongruent findings by Chazin and Neuschatz (1990), that song-based learning advantage does not endure in the long-term, may be explained by assuming that those study participants "simply concentrated their effort on learning the more difficult aspects of the material, single words, whereas in the current study more "chunking" of words into phrases may have been possible" (McElhinney & Annett, 1996, p. 398). Although the quite small sample size of this study may call into

question its validity and generalizability, it is becoming apparent that using small, convenience sampling methods without concern for statistical power is normative within this literature and demonstrates an opportunity for further research in this space utilizing more robust study methodologies. The mixed-factorial study design and the congruence of findings with Wallace (1994), including noting that song may lead to chunking of information which aids retention and recall, further strengthen the argument in favor of song-based instructional techniques.

Kilgour et al. (2000) further investigated the mechanisms by which music may facilitate learning verbal information in a three-arm study. In the first arm of this experimental study, the authors analyzed whether pre-existing knowledge or expertise in music impacts the effectiveness of song-based instruction; Wallace (1994) had shown that musical expertise does *not* have an impact. In this study, 78 undergraduate psychology students were asked to remember textual information after hearing words in either spoken form or sung form four times. Recall was tested after the first, second, and fourth exposures and again 15 minutes after the final exposure. Words were recalled best in the sung versus spoken condition overall, with song-advantage becoming significant after the second and fourth exposures and in the delayed condition ($F(4,144) = 3.48$, $p < .01$). Students with musical training had significantly better recall overall than those who did not in both conditions ($F(1,72) = 19.27$, $p < .0001$).

In a second arm, Kilgour et al. (2000) repeated the methods of the first experiment but controlled for the IQ of participants as measured by the Kaufman Brief Intelligence Test (Kaufman & Kaufman, 1990). Forty undergraduate psychology students were divided into groups and exposed to verbal information in either sung or spoken form. In

this experiment, the delivery speed of both exposures was approximately equal. The findings showed that those exposed to verbal information in the *spoken* condition had superior recall scores overall compared to those exposed to the same information through song ($F(1,36) = 7.21$, $p = .011$). Again, participants with musical training had superior recall in both treatments ($F(1,36) = 13.54$, $p < .001$) even when controlling for intelligence.

Now hypothesizing that speed of delivery may be the mechanism by which song advantages learning, Kilgour et al. (2000) conducted a third study with 120 undergraduate psychology students who were again divided into groups and asked to remember textual information after hearing it in either spoken or sung form. However, this time six groups were formed to test recall when song or spoken words were delivered at slow, normal, or fast speeds with the speed of presentation equalized in sung and spoken conditions at all three speeds. Those exposed to the spoken condition had an increase in recall versus sung condition, though not reaching statistical significance ($F(1,108) = 3.76$, $p = .055$). Recall was better at slower presentation speeds ($F(2,108) = 14.26$, $p < .0001$).

The Kilgour et al. (2000) study was a landmark study, novelly suggesting that the mechanism by which song might effectively help with knowledge recall has to do with the slower speed at which sung information is often presented and not with its musical nature. This result called into question previous, older studies which attributed the song advantage to melody acting as a retrieval cue for lyrical information (Calvert & Tart, 1993; McElhinney & Annett, 1996; Wallace, 1994). It also called into question Wallace's (1994) findings regarding whether musical ability enhances the utility of song as a

memory aid, showing that musical ability improves recall in general even when controlling for intelligence. Although this study calls into question the *mechanism* of song advantage, this *is* yet another study which supports the use of song to aid in the retention of information in the short term. It also suggests that there is an opportunity for further analysis beyond the quantitative methods employed so far to explore *how* students use song to learn through qualitative methodology.

Rainey and Larsen (2002) noted that the only previous research showing that song may aid in *long-term* retention of information was by Calvert and Tart (1993). To add to this body of evidence, Rainey and Larsen (2002) designed an experimental study to test how song impacts the speed at which new information can be learned and how song impacts retention of new information in long-term memory. They intentionally chose to test retention of unconnected text, which they defined as "lists in which the elements have little or no inherent connection" (p. 179) (such as Chazin and Neuschatz's (1990) list of minerals), which are thought to take a longer time to learn than connected text like the words of the constitutional preamble as in Calvert and Tart's (1993) study.

In this study, 79 undergraduate students (discipline unspecified) were asked to learn a list of baseball player names. The authors chose names of players from the 1948 World Series because they "were unknown to the participants" (Rainey & Larsen, 2002, p. 179), though did not describe the method by which this lack of knowledge was assessed. Half of the participants heard the names sung to the tune of "Pop Goes the Weasel" while the other half heard the words spoken at a similar pace. Participants could listen to the list as many times as needed to correctly recall the information, and the

number of times needed to learn the information was recorded. Recall was again tested one week after the initial session.

In the initial session, there was not a statistically significant difference ($t(77) = 0.28$, $p = .78$) between learning in the sung ($M = 27.75$, $SD = 16.32$) versus the spoken condition ($M = 28.72$, $SD = 14.94$). This was in support of the findings of Kilgour et al. (2000) that when controlling for speed, the mnemonic advantage of song is diminished. However, when retested one-week later, the song-based group ($M = 4.65$, $SD = 3.75$) was able to recall the list of names statistically significantly faster ($t(77) = 2.07$, $p = .04$) than the spoken group ($M = 6.72$, $SD = 5.02$). Rainey and Larsen (2002) repeated this method with a new list of names adapted from names of characters in J.R.R Tolkien's book *The Hobbit* "using the same number of syllables and the same consonant and vowel structure as the original names" (p. 182). These names were set to the tune of "Yankee Doodle" and found, again, that while there was no immediate advantage to song when controlling for speed of delivery ($F(2, 99) = 16.68$, $p < .001$), there was faster recall of information after one week when the information was initially learned in a song-based format ($F(2, 99) = 5.33$, $p = .006$).

Rainey and Larsen (2002) suggested that the immediate song-advantage found in previous studies (McElhinney & Annett, 1996; Wallace, 1994) may be related to the use of songs with connected text in those studies versus the unconnected text used in this one. The experimental nature of this study and its interconnectedness to prior study results adds additional depth to the understanding of mechanism by which song may help with retention and recall of information in the long-term beyond just the speed of delivery. It also helps to confirm the findings of Calvert and Tart (1993) for song's ability to help in

long-term recall specifically. When thinking of the best use of song within PA education, the findings of this study may indicate that it may be important to create topical songs with connected lyrics versus simply setting unrelated words to melody to maximize long-term recall of information.

Racette and Peretz (2007) noted that while previous studies had shown that learning information as lyrics to a song aids in later recall of that information, most previous studies assessed recall through writing despite presenting information in an aural format (speaking or singing). Racette and Peretz (2007) conducted an experimental study to investigate the efficacy of song-based instruction for recall of verbal information with an oral assessment method. In their study, 36 French-speaking undergraduate students, half with musical experience, were asked to learn French-Canadian folk songs. Song lyrics were presented to participants line by line, and participants were then asked to repeat the lyrics. The study included three experimental conditions depending on whether the lyrics were initially presented in a sung or spoken manner and whether the recall of lyrics was sung or spoken (sung-sung, sung-spoken, spoken-spoken). Unlike Kilgour et al. (2000) and Rainey and Larsen (2002), speed was not controlled for, and information was delivered more slowly in the sung presentation. Accuracy of recall was assessed during the trial and 15 minutes afterward. In response to Rainey and Larsen (2002), 25 participants were contacted seven months following the experiment to test whether there was a long-term benefit of song-based learning.

Racette and Peretz (2007) found that participants who were asked to recall information in a sung manner ($M = 60\%$) recalled statistically significantly fewer words ($F(2,68) = 11.78$, $p < .001$) than those asked to recall information in a spoken manner

regardless of whether they were exposed to it in a sung (M = 70.9%) or spoken (M = 74%) manner. There was no statistically significant difference in text recall between musicians and non-musicians. Boldly, the authors declared that "there was not the slightest indication that music helped in the long run, since the addition of music during song presentation or during participants' responses had no effect on long-term recall" and suggested that "it is possible that participants treated music as a secondary task, and hence treated it as an additional demand rather than as an aid to memory" (Racette & Peretz, 2007, p. 248).

The findings of Racette and Peretz (2007) may seem potentially disruptive to the argument being presented thus far that tying information to melody in the form of a song can effectively improve retention and recall of information. However, there are several notable aspects of this study which call into question its generalizability to a HPE classroom. Perhaps most obvious is that students in the health professions, such as PA students, would never be asked to sing information as a form of assessment. Furthermore, the lyrics of French-Canadian folk songs include information that is perhaps not of particular interest to the participants of this study and may have impacted their motivation for learning. The statistical analysis, which included means without reported standard deviations, is also unconventional. While the findings by Racette and Peretz (2007) are notable, both the limitations in internal and external validity should be considered in the application of their results.

In response to Racette and Peretz (2007), Ludke et al. (2014) conducted an experimental study within a sample of 60 English-speaking adults to test the impacts of song on learning new verbal information. Ludke et al. (2014) suggested that the negative

findings of Racette and Peretz (2007) may have been influenced by the complex melodies of songs chosen in that study instead of using a simple melody as suggested by Wallace (1994). In their study, Ludke et al. (2014) used phrases in the Hungarian language to control for any mnemonic clues that may be provided by learning information in one's own language and set the Hungarian "lyrics" to simple melodies. The sample (n = 60) was randomized into three groups that were exposed to the Hungarian phrases either via a spoken recording, a spoken recording which matched the rhythm of song, or a sung recording. The speed of delivery between the spoken and sung recordings was equalized in response to the findings of Kilgour et al. (2000) that it is the slow speed of delivery that makes verbal information easier to learn in sung conditions. After hearing and practicing phrases for 15 minutes, participants took several Hungarian language tests.

Results demonstrated that the singing treatment resulted in more effective learning of the foreign language than the other treatments when asked to recall and reproduce short phrases ($t(38) = 2.38$, $p < .05$, $d = 0.75$). The authors specifically controlled for a speed advantage in this study by including the spoken-rhythmic group which were exposed to the phrases at the same speed as the song group and still found an advantage to song. Ludke et al. (2014) claimed that they were the first to use a randomized, controlled, experimental design to demonstrate the effectiveness of song as a tool to learn new verbal information. The robust methods of this study add credibility to the findings. In addition, this study offers an important response to Kilgour et al. (2000) in that it demonstrates that the mechanism behind the song-based learning advantage is likely more than just speed of delivery.

Building upon the experimental design of Ludke et al. (2014), Lummis et al. (2017) designed a mixed-factor experimental study in order to re-investigate questions previously studied by Wallace (1994) and McElhinney and Annett (1996): is verbal information better learned in a sung versus spoken condition, and does musical ability impact this phenomenon? To gain greater insight into the learning experience of students, in addition to recall, the authors also calculated cluster scores to evaluate whether words were learned in chunks or as single words. Participants also completed a survey which asked about perception of whether learning through song impacted cognitive load.

Ninety-four undergraduate psychology students, approximately half (47%) of who were considered musicians, were recruited into the study (Lummis et al., 2017). Musicianship of participants was determined "based on a survey about past musical experience" (p. 144). Surveys were reviewed by two researchers who decided whether each participant would fit the description of a musician in the context of the current study based on the extent of their past musical training. Two songs were used in this study. Recordings were created for each song with lyrics presented in both sung and spoken conditions. Participants were then exposed to one song in either a spoken condition or sung condition and recall was tested. One week later, participants returned and were exposed to the other song in the opposite condition. At the end of the second session, long term recall for the first set of lyrics was tested. A questionnaire regarding perceived task-load was administered after both sessions.

Analysis of variance (ANOVA) demonstrated that immediate word recall was statistically significantly higher ($F(2, 188) = 438.65$, $p < .001$) in the sung condition ($M = 36$, $SD = 0.16$) than in the spoken condition ($M = 0.32$, $SD = 0.15$). This advantage of the

sung condition for word recall persisted after 1 week ($F(1, 92) = 4.96$, $p = .029$). There was no significant difference in immediate recall for musicians vs. non-musicians ($F(1,92) = 2.79$, $p = .099$), but a significant difference was apparent when testing recall after 1 week ($F(1, 92) = 5.82$, $p = .018$) which was better in the musician group ($M = 0.31$, $SD = 0.17$) compared to the non-musician group ($M = 0.23$, $SD = 0.16$).

The authors also tested whether information was being learned in chunks versus single words impacted learning in both conditions. They found a significant difference in these immediate "cluster scores" ($F(1, 92) = 16.32$, $p < .001$) between conditions, with that the music condition resulting in statistically significantly more chunking of information ($M = 11.80$, $SD = 7.76$) compared to the non-music condition ($M = 9.71$, $SD = 6.35$). This difference persisted after 1 week ($F(1, 92) = 7.40$, $p = .008$) with cluster scores persistently higher in the music ($M = 9.03$, $SD = 7.34$) versus non-music condition ($M = 5.42$, $SD = 4.80$) (, $p = .008$). Interestingly, survey results showed that participants felt significantly more pressured for time ($F(1, 92) = 4.09$, $p = .046$) in the sung condition ($M = 4.69$, $SD = 1.66$) than in the spoken condition ($M = 4.38$, $SD = 1.45$) but felt they were more successful ($F(1, 92) = 10.34$, $p = .002$) in the sung condition ($M = 4.19$, $SD = 1.21$) than in the spoken condition ($M = 3.81$, $SD = 1.11$).

Lummis et al.'s (2017) study used a rigorous experimental study design to add to the body of literature in support of song as a mnemonic device. Not only did the authors show the efficacy of song for recall of information, they also advanced the understanding of this phenomenon by showing that information learned in a song format is more likely to be learned in chunks which likely aids in its later recall and suggest that "learning information set to music may be useful in situations ranging from detailed memorization

to the learning of general concepts and ideas" (p. 148). As described above, the authors found that musicians had significantly better long-term recall than non-musicians which may call into question the external validity of these results within a heterogeneous musical student population, such as would be expected within HPE contexts. However, even non-musicians had better short-term recall and were more likely to chunk information when learning information through song. These conclusions support a broad application of song-based instructional techniques, including within a HPE setting. Furthermore, the assessment of student perceptions of how song-based instruction impacted their learning process suggests room for additional inquiry into subjective experiences through qualitative methods.

This collection of studies from the psychology literature have shown via various methods that song is an effective tool for the retention and recall of verbal information. Some studies have shown that the musical ability of a student impacts the effectiveness of song (Kilgour et al., 2000; Lummis et al., 2017) while others have not (Wallace, 1994). Some authors believed that the benefit of song is due to the way that melody and lyrics are encoded (McElhinney & Annett, 1996; Wallace, 1994), while others believed that the benefit is related to a slower speed of information delivery (Kilgour et al., 2000).

Regardless, there is evidence over the 30 years of research represented here that learning information as lyrics tied to melody is superior to learning the same information in a non-song-based way. However, these studies were conducted with the intention of testing psychological hypotheses and not for the purposes of curricular evaluation. Therefore, additional evidence is needed to determine the effectiveness of song within an educational context and to further explore the perceptions of learners regarding how song

effects their acquisition of knowledge. In the next section, evidence from the education literature will be presented to show examples of song-based instruction being utilized in the context of post-secondary science education.

Song-based Instruction in Undergraduate Science Education

The field of biochemistry is ripe with examples of musical instructional techniques, particularly of setting lyrics to familiar melodies. Ahern (2006a, 2006b) has been particularly prolific, with 32 published sets of song lyrics about biochemistry concepts including "God Rest Ye Merry Lipoproteins" and "The Battle Hymn of Biochemistry". Gilbert (2006), another biochemist, has published lyrics to a song called "The Histone Song (To the Tune of 'The Flintstones'). The lyrics of these songs are offered without explanation regarding the educational setting in which they were delivered or any data regarding their efficacy. However, they are included in this review to demonstrate that song is being used in the real-world context to teach scientific concepts. All of these songs share the approach of writing content-specific lyrics to well-known melodies, which could have the benefit of helping with encoding of information (Tamminen et al., 2017).

McLachlin (2009) described using Gilbert's (2006) song about histones in a biochemistry lecture course at the University of Western Ontario. McLachlin (2009) used the song in a large lecture hall setting with 400-800 undergraduate students in attendance. The song lyrics were projected onto a screen, and the students were invited to sing the song out loud and clap to the beat of the music with the instructor. Students were then surveyed about their experience with the in-class activity. Of the 1192 students enrolled in the course, 599 surveys were returned (50.3% response rate) and the following findings were identified: 69% of the students sang in class, 81% clapped, 75% of students

indicated that they enjoyed the song "very much", 55% of students indicated that they sang the song five weeks after the lecture, and 44% felt that the song would be helpful to them when they studied. McLachlin (2009), interestingly, also surveyed students regarding their familiarity with 30 common songs to identify melodies with which students are likely to be most familiar, recommending that the more familiar melodies be chosen to pair with content-specific lyrics.

McLachlin's (2009) study provides us with some data regarding the use of song in his teaching. However, his methods are not well described, and his statistics are descriptive at best, measuring student participation, engagement, and enjoyment of the activity instead of measuring if the activity helped students learn. His determination of popular melodies in his student population may have been relevant at the time of publication in 2009 but are likely somewhat outdated now. This study does demonstrate, however, application of the previously published lyrics and suggests that it was a popular exercise with students.

Moving beyond biochemistry, Dickson and Grant (2003) described writing novel song lyrics about physics concepts and setting them to familiar melodies to teach fundamental physics to students in lecture, workshop, and "science roadshows" in Liverpool, England in the early 2000s. They called this venture "Physics Karaoke". One example was a song called "Hey Joule", set to the song "Hey Jude" by the Beatles, in which the first law of thermodynamics was explained. In the article, Dickson and Grant (2003) discussed their motivations for creating this content, focusing primarily on wanting to use familiar music to demystify physics for students who are new to the field, to "present and promote scientific ideas and understanding" (p. 321), and to "make the

connection with other aspects of the student's experience via the mode of presentation and learning" (p.320). While the authors provided several samples of song lyrics in this article and make arguments as to why they think this method of teaching is effective, they present no data which measures its impact. This study provides an example of how music is being used to teach information in a science education setting but fails to provide any information regarding whether it was successful as a learning tool or, even, as an entertainment tool.

Chan (2006) published an essay in the Lancet which describes her use of song to teach undergraduate students enrolled in a general education health science course in Hong Kong about the infectious disease dengue fever. Chan (2006) first presented a lecture and a video about dengue fever to students. Instead of writing a song herself for students, she instructed six small groups of students to write their own songs about what they had learned and then perform the songs for the larger group at the end of the class session. Chan (2006) then described the songs that the students created. Four groups wrote songs with familiar melodies while two groups created novel melodies. She described that, "most of the students were self-motivated and active" and that students "worked with their classmates in an atmosphere of mutual trust and appreciation" (p. S22).

While Chan's (2006) essay provides a thorough description of the activity, again there were no outcomes measured to show whether it was an effective teaching tool. However, Chan (2006) does make an interesting statement about outcomes at the end of the essay: "Composition of a song to master medical knowledge can be regarded not only

as outcome based, but also as process based, because every group member has to contribute to the discussion and negotiation before the song can be completed" (p. S23).

Within the undergraduate science literature, we have seen several examples in which scientific information is presented to students in the format of lyrics set to familiar songs and some evidence to suggest that students at least find this approach enjoyable. We have even seen an example in which students were asked to compose their own songs with content-specific lyrics as a learning activity within a course (Chan, 2006). What we have not seen is any substantial quantitative methodology to demonstrate whether this is an effective instructional technique or evidence to corroborate the findings previously described from the psychology literature that song can be an effective memory tool.

In addition, we have not seen any formal qualitative exploration regarding how learners *perceive* that song effects how they process and acquire new knowledge. Of note, there have been no mixed methods studies presented at all in this literature review which, given the general paucity of evidence here, could be a methodology which provides both depth and breadth to our limited understanding of this concept. Furthermore, the most recent of the studies presented in this section (McLachlin, 2009) is now 16 years old, demonstrating that there is a growing gap in evidence which supports the use of song within science education. The next section will show that this gap extends into the HPE literature as well and will illustrate the need for new research with robust methodology to better understand the potential impacts of a song-based instructional approach for health professions learners.

Song-based Instruction in Health Professions Education

Within the HPE literature, Hermanns et al. (2012) described using music to teach psychopharmacology concepts to nursing students. Like the previously reviewed studies

in the undergraduate science literature, in this study content-specific lyrics were written and set to familiar melodies ("Brahm's Lullaby" and "Three Blind Mice"). Unlike McLachlin (2009) who asked students to sing the song out loud during a class session, Hermanns et al. (2012) made recordings of the songs available to students in MP3 format through a learning management system and students were able to access the content outside of class time.

Hermanns et al. (2012) describe their use of song to teach nursing students and present anecdotal accounts of positive student reactions to the songs. One student was quoted as saying, "The songs are stuck in my head to this day!" and another as saying, "They are annoying…but that seems to make them stick in my head better" (Hermanns et al., 2012, p. 520). Another student described downloading the songs and listening to them when completing tasks such as driving and exercising, and another felt that the songs were helpful memory tools (Hermanns et al., 2012). While these examples show the nursing students perceived the use of song as helpful to remember psychopharmacology content, like Dickson and Grant (2003), Hermanns et al. (2012) offers no evidence to objectively measure whether or not this was an effective way for students to learn about psychopharmacology, either qualitatively or quantitatively.

Chan (2014), also in the nursing education literature, published a study in which songwriting was incorporated into a problem-based learning session within a nursing program. Small groups of nursing students ($N = 20$, divided into four groups of five students) were asked to write and perform songs about a case involving a patient with epilepsy. Afterward, the students participated in a focus group interview in which they were asked to summarize what they learned from the session and to reflect on the

experience. Chan (2014) then analyzed the focus group transcripts for themes to explore student attitudes toward the use of song writing within nursing education.

Results of Chan's (2014) qualitative data analysis indicated that the nursing students felt the activity positively impacted their learning and problem-solving, helped with memorization of content, and generally made learning more engaging. These conclusions offer a second example of a song-based instructional method being utilized in a health professions education classroom, though in this case, students generated the songs themselves versus being provided instructor generated songs. Also, like Hermanns et al. (2012), no outcomes were measured regarding the effectiveness of song as a memory tool.

With only a few studies exploring song-based instruction within the field of HPE, and no studies specifically within PA education, there is clearly a need for further research on this concept. Methodologically, there have been no quantitative studies within the HPE literature which formally assess the effectiveness of song as a tool for the retention and recall of the foundational information which all beginning HPE students, regardless of discipline of study, must acquire before advancing to higher order learning activities. Furthermore, there have been no studies within this literature which use a qualitative approach to better understand how learners perceive that music effects knowledge acquisition, and certainly no studies which utilize mixed methods to deepen and broaden understanding.

An Opportunity to Integrate Song-Based Instruction in PA Education

As has been previously shown in this literature review, there is decades worth of evidence in the psychology literature supporting the effectiveness of song as a tool for

learning scientific information (Chazin & Neuschatz, 1990), fostering retention for many years after initial learning (Calvert & Tart, 1993), and the ability to use song as an instructional strategy "in situations ranging from detailed memorization to the learning of general concepts and ideas" (Lummis et al., 2017, p. 148). There are a few, mostly descriptive, accounts of song being utilized within undergraduate science classrooms (Chan, 2006; Dickson & Grant, 2003; McLachlin, 2009). There are even fewer accounts within the HPE literature.

Within the scant HPE literature, studies are without rigorous methodology, are not designed to measure study outcomes or to explore how learners perceive that song-based instructions effects knowledge acquisition and are clustered within the field of nursing (Chan, 2014; Hermanns et al., 2012). There have been no publications within the PA education literature studying the effect of song-based instruction, and yet there is a clear need within this field for improved instructional techniques to assist learners in the long-term retention of scientific knowledge, particularly within the low-scoring topic area of hematology. This study sought to address this gap in the PA education literature by studying the effect of and exploring perceptions of song-based instruction on first-year PA students' acquisition of hematology knowledge using a mixed-methods approach.

Theoretical Framework

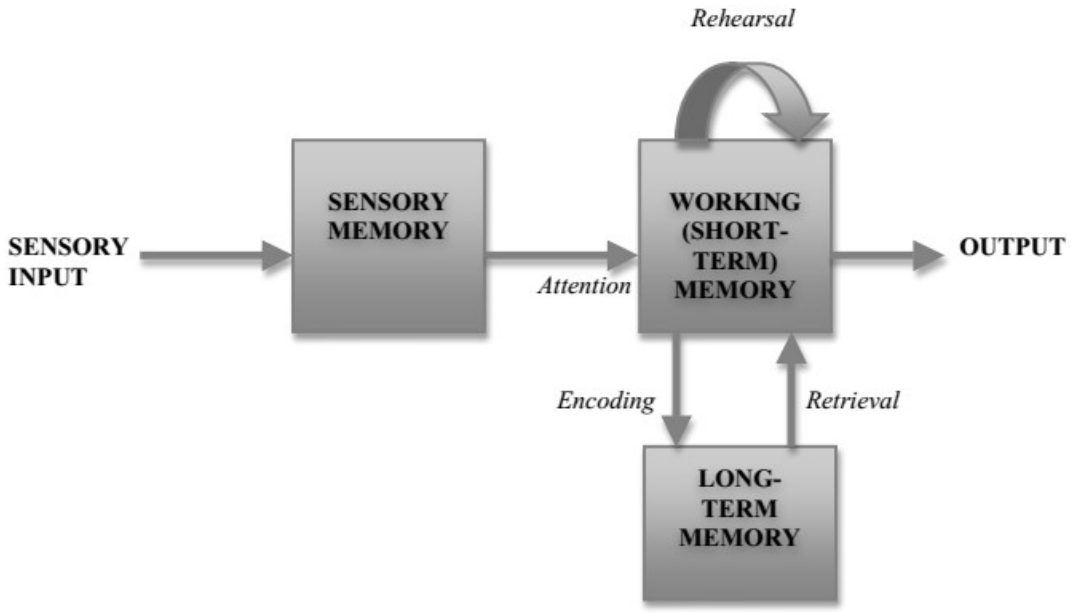
The theoretical framework for this study is information processing theory. Inspired by early computer science, the psychologist George Miller first developed a theory of human information processing in the 1950s. Information processing theory attempts to explain how humans construct information in their minds (Miller, 1956). Prior to this, the predominant learning theory of behaviorism dealt mostly in stimulus-

response pairings without regard for mental constructs (Thorndike, 1932). Miller's information processing theory was a first attempt to describe how humans take in information, process and store that information in memory, and later retrieve it (encoding, retaining, and retrieving), similar to a computer processor (Miller, 1956).

Contemporary to Miller, Atkinson and Shiffrin (1968) further theorized how information is processed in the human mind with a focus on memory called "the three-stage information processing model" (Figure 1). In the Atkinson-Shiffrin model, memory is thought of in three stages: sensory register, short-term memory, and long-term memory. Information first enters the mind as sensory input (e.g., sights, smells, sounds) and is held in the sensory register briefly until it is perceived, or assigned meaning, at which point the information enters short-term memory (Atkinson & Shiffrin, 1968).

Figure 1

Information Processing Model



Note. From *File:IPADiagram.PNG*[Image], by Wikimedia Commons Contributors, 2020, Wikimedia Commons (https://commons.wikimedia.org/w/index.php?title=File:IPA_Diagram.PNG&oldid=438102633). CC BY-SA 3.0.

Short-term memory (referred to as "working memory" in later models) has limits to the amount of information it can process. Miller famously quantified that short-term memory can only process seven (plus or minus two) units of information at one time (Miller, 1956). For information to remain in short-term memory, it must be repeated, or "rehearsed". Without rehearsal, and with only room for five to nine pieces of information at a time, information can be lost from short-term memory. Following rehearsal in short-term memory, information is matched with related information in long-term memory where it is stored, theoretically, for the lifetime of the person (Atkinson & Shiffrin, 1968). Though humans receive a near constant stream of information into the sensory registers, very little information is rehearsed in the short-term memory and transferred to

long-term memory. Perception occurs when new information is recognized as familiar, or meaningful, and linked to information already present in the long-term memory. Perception can be driven by the sensory inputs themselves (bottom-up processing) or by our expectations (top-down processing) (Ashcraft & Radvansky, 2014).

Encoding is the process by which perceived information is readied for storage and integration with existing information in long-term memory (Schunk, 2020). Whether or not information will encode is influenced by elaboration and organization. Elaboration is when new information is connected to pre-existing information (Anderson, 1990). Organizing information into groups creates connection between individual pieces of information which facilitates encoding but also facilitates recall of that information which is essential for meaningful learning (Miller, 1956). Using mnemonic devices is one way in which information can be both elaborated and organized. An example of this is remembering that the first letter of each Great Lake (Huron, Ontario, Michigan, Erie, Superior) spells the words HOMES (James Madison University, n.d.). Elaboration and organization are both integral to the formation of schemas, or systems of information (Schunk, 2020).

Retrieval is the process by which someone accesses information stored in long-term memory. There is evidence to suggest that information which is encoded together is later best retrieved together, a concept known as “encoding-retrieval similarity” (Baddeley, 1997). Practically, when trying to retrieve information, it can be helpful to provide cues which were also present at the time of encoding, or to create an environment similar to that which was present at the time of encoding (Schunk, 2020).

Information processing theory is relevant to this study as it has been hypothesized that the mnemonic effect of song-based instruction can be attributed to the enhancement at both the encoding and retrieval stages of information processing. Music is thought to enhance the encoding process of connected verbal information by engaging "a broad and complex neural network" with "music recruiting a broader network of brain areas during encoding than non-musical presentation" (Tamminen et al., 2017, p. 108). At the time of retrieval, the melody acts as a cue for retrieval of the associated verbal information by providing "a framework that indicates how much information must be recalled, where information has been omitted, as well as the order of segments" (Wallace, 1994, p. 1482). The mixed method approach of this study allowed for quantitative assessment of the effect of a song-based instructional approach on learning and for qualitative exploration of how students perceive the song-based approach effects processing of information.

Summary

In summary, this literature review supports the use of a song-based instructional approach with three decades of psychological studies demonstrating the efficacy of song to enhance both retention and recall of associated verbal material (Calvert & Tart, 1993; Chazin & Neuschatz, 1990; Ginsborg & Sloboda, 2007; Kilgour et al., 2000; Ludke et al., 2014). Examples of song-based instruction within undergraduate science classrooms (Ahern, 2006a, 2006b; Chan, 2006; Dickson & Grant, 2003; McLachlin, 2009) show that there is a role for this humanities-based method in the instruction of scientific topics, though its efficacy has not been rigorously studied in this context. Within HPE, there are only two published examples of song-based instruction (Chan, 2014; Hermanns et al.,

2012), both within the nursing literature and both without sound quantitative or qualitative methodology to measure outcomes of this learning intervention.

There has been no research in PA education exploring the use of song as an educational tool despite a need for improved instructional techniques in foundational medical topics within this field, especially within the topic of hematology. Information processing theory provides a cogent framework for understanding how song impacts learning through enhancement of both encoding and recall of information when learned through song. In the next chapter, I will discuss the methodology for my embedded mixed-methods study aimed at understanding the effect of song-based instruction on first-year PA students' hematology knowledge acquisition.

CHAPTER 3: METHODS

Introduction

This chapter describes the methodology used to conduct this study, including the research design, research questions and hypotheses, and data collection and analysis procedures. A statement of researcher positionality will be presented, and trustworthiness will be addressed including ethical considerations. The purpose of this embedded mixed methods study was to determine whether song-based instruction impacts medical knowledge acquisition as measured by summative exam scores on a hematology module in first-year PA students and to explore student perceptions of song-based instruction on their medical knowledge acquisition.

Research Design

This study used an embedded mixed methods design. Mixed methods study designs include “elements of qualitative and quantitative research approaches…for the purposes of breadth and depth of understanding” (Johnson et al., 2007, p. 123). An embedded mixed method study embeds a qualitative component within an experimental, quantitative study in order to "explore in more detail the outcome results and explain why the intervention may or may not have worked” (Creswell & Plano Clark, 2018, p. 108). In this embedded mixed methods study, a qualitative component was embedded within the quantitative design. This method was appropriate for this study because it allowed for an informed interpretation of the quantitative findings regarding the impact of song-based instruction on knowledge acquisition through the addition of the supporting, qualitative component which provided in-depth insights into student perceptions of how song-based instruction impacted their learning.

In the quantitative component of this study, a quasi-experimental, posttest only design was employed. Quasi-experiments include non-random allocation of participants to groups and is a commonly utilized study design in educational research due to the "need to use intact groups" (Creswell & Guetterman, 2019, p. 313). A posttest only design is used in an experimental or quasi-experimental study in which outcomes are measured via an assessment administered after exposure to the intervention (Creswell & Guetterman, 2019). The dependent variable in this study was summative examination scores for a hematology module. The two groups included a control group receiving traditional lecture-based instruction and an intervention group receiving lecture-based instruction that included songs with content-specific lyrics. To supplement this data, qualitative interviews were conducted with students in the intervention group and thematic analysis of interview transcripts was performed.

Research Questions and Hypotheses

The research questions and hypotheses for this study are as follows:

RQ1: Is there a difference in hematology module summative exam scores between first-year PA students who participate in song-based instruction and those who do not?

H_0: There is no difference in hematology module summative exam scores between first-year PA students who participate in song-based instruction and those who do not.

H_A: There is a difference in hematology module summative exam scores between first-year PA students who participate in song-based instruction and those who do not.

RQ2: How do students perceive their acquisition of foundational hematology knowledge through song-based instruction?

Participants and Sampling

First-semester, didactic-phase PA students from one PA program in New England enrolled in a hematology module in the spring 2024 and 2025 semesters were included in this study. Fifty students are enrolled in this module each year, therefore, a sample size of 100 students was achieved in the quantitative component of this study across the two cohorts. The 50 students enrolled in the course in spring 2024 served as the control group and the 50 students enrolled in the course in spring 2025 served as the intervention group. A convenience sampling method, a type of nonprobability sampling in which participants are selected "because they are willing and available to be studied" (Creswell & Guetterman, 2019, p. 143), was utilized for this study as all enrolled students in the hematology module during the years studied were included in the sample. A priori power analysis was conducted using G*Power version 3.1.9.7 (Faul et al., 2007) and results indicated that a total sample size of 100 would achieve 70% statistical power for detecting a medium effect size (Cohen, 1988) at a significance of $a = .05$. Though Cohen (1988) asserted that, "it is proposed here as a convention that, when the investigator has no other basis for setting the desired power value, the value .80 be used" (p. 56), the ability to increase sample size to achieve a power of 80% was impracticable in this study due to the predetermined class size in both control and intervention groups.

In the qualitative component of the study, students who completed the hematology module in the spring of 2025 were invited to participate in semi-structured interviews. Maximum variation sampling was used to determine the students selected for

interviews from the sample of volunteers. Maximum variation sampling involves "determining in advance some criteria that differentiate the…participants and then selecting…participants that are quite different on the criteria" (Creswell & Poth, 2018, p. 158). The criterion chosen in advance for this study was summative examination score, with an intent to select participants with a range of scores on the summative examination to collect heterogeneous data. After piloting the interview script with two students from the spring 2025 cohort, nine additional students from the same cohort were invited to be interviewed. Because there were no changes made to the interview script after the two pilot interviews, both pilot interviews and the nine additional interviews were included in data analysis for a total of 11 interviews, at which point thematic saturation was achieved.

Procedures

IRB Application, Recruitment, and Informed Consent

Approval to conduct this study was obtained from the Tufts University Health Science Institutional Review Board (IRB). All PA students enrolled in the hematology module during the spring 2024 and spring 2025 semesters were included in the primary analysis in the quantitative arm of the study. Because examination scores were reviewed retrospectively and because the examination was administered as part of normal educational practices, consent for inclusion of examination scores in the analysis was not obtained at the recommendation of the IRB.

During the first week of the hematology module, students in the spring 2025 course were invited via email to complete the musical experience survey (Appendix A). An IRB approved consent information sheet was attached to this email (Appendix B). A subset of students from the spring 2025 course (intervention group) were invited via

email (Appendix C) to participate in qualitative interviews after the conclusion of the course and a second consent information sheet provided to interviewees (Appendix D).

Hematology Module

All students enrolled in the PA program were required to successfully complete a hematology module which is offered once each year during the first (spring) semester of the program. The hematology module consists of eight, two-hour classroom sessions and one two-hour review session which were scheduled over a period of five weeks. The first six lectures cover benign (non-cancer) hematology topics and were taught by me. The final two lectures cover malignant hematology topics and were taught by a PA who practices in the field of hematology-oncology. The module concluded with a 50-item, multiple choice summative knowledge assessment, described in detail below. Topics covered in the module were chosen to align with the NCCPA PANCE hematology topic list (see Appendix E) (National Commission on Certification of Physician Assistants, n.d.-b). The NCCPA PANCE topic list reflects the baseline hematology knowledge that newly graduated PAs are expected to have acquired during their PA education.

Lecture-Based Instruction Group vs. Song-Based Instruction Group

In the quantitative arm of this study, the class of students who completed the hematology module in 2024 served as the control group. These students received traditional, lecture-based instruction. The class of students who completed the hematology module in 2025 served as the intervention group. These students similarly received lecture-based instruction but with the inclusion of a song in each lecture which was written with lyrics specific to a topic or concept being taught in that lecture. Otherwise, instruction for both groups included identical topics, learning objectives, and sequencing and were taught by the same instructors. Both groups were assessed via

identical multiple-choice examinations which are the routine summative assessment tools in all modules and courses within the PA program. The *only* difference between groups was the inclusion of song. No changes (other than the inclusion of song) were made to the hematology module after its delivery in 2024, including but not limited to number of instruction hours, instructional objectives, course learning outcomes, instructor, classroom setting, assessment method, and sequencing within the PA program.

In the intervention group, I created songs with lyrics that pertained to a key concept or concepts covered in each lecture for a total of eight songs (see Appendix F). Each content-specific song was presented by me during lecture. Audio video recordings of lectures throughout the PA program were captured and made available to students to review outside of class. Audio-only (MP4) recordings of the songs were created and made available to students as electronic media files via the learning management system for review outside of class. A video playlist, which included audiovisual recordings of all eight songs, was also created and made available to students through YouTube (see Appendix F). Four of the songs were written using a familiar melody and four of the songs were written with novel melodies. Though Kilgour et al. (2000) studied whether the inherently slower delivery speed of verbal information when sung versus spoken is the mechanism by which song imparts a learning advantage, this study did not include speed as a variable because understanding mechanism of song advantage was not an aim of the quantitative component of this study.

Data Collection

Instrument

The primary source of quantitative data was summative hematology examination scores from the spring 2024 and 2025 iterations of the module. All students enrolled in the hematology module took a 50 item, multiple-choice examination one week following the concluding lecture of the module to assess knowledge acquisition. Each item included four response options (one correct answer, three distractors). Twenty-one out of the 50 total exam items on the summative module examination tested knowledge of topics included in song lyrics. The remaining 29 items covered topics covered in lectures but not in song lyrics. See Appendix G for a list of lecture and song topic and associated number of examination items. Students were allotted 80 minutes to complete the exam.

Scores were calculated and reported as percentage overall correct out of the 50 total items, with a score of 80% or above considered a passing score. The exam was taken in person on a laptop or tablet with a proctor present to ensure exam security and academic honesty. It was administered through and automatically scored by the ExamSoft software platform (ExamSoft Worldwide, Inc., 2025). ExamSoft also automatically calculates psychometrics for each testing item and a Kuder-Richardson (KR-20) reliability coefficient for all assessments administered through the platform. The KR-20 for the spring 2024 administration of the exam was 0.44 and for the spring 2025 administration of the exam was 0.54.

I created the hematology examination based on my experience as a PA clinician-educator with six years of experience in PA education who had completed doctoral-level coursework on assessment in health professions education. The validity of the

examination is supported through alignment of the examination blueprint with the learning objectives of the module. The topics covered within the module are congruent with the PANCE hematology section topic list (National Commission on Certification of Physician Assistants, n.d.-a), which further supports validity. The module, including examination content and psychometric data, is reviewed annually by the program's director of didactic education and reviewed every three years by the program's curriculum committee.

Demographic data (age, gender, race/ethnicity) were collected for both groups of students from PA program administrative records. Information regarding musical experience was collected from students in the spring 2025 cohort via a Qualtrics survey (Qualtrics XM, 2025). Survey questions were modeled after those used by Wallace (1994) and included questions about formal singing experience, musical instrument playing, and ability to read music. As per Wallace (1994), for the purposes of this study "musical experience" was defined as formal experience with singing or instrument playing. This survey also included a question about interest in participating in qualitative interviews (Appendix H).

Interviews

Qualitative data were collected through a series of 30–45-minute, semi-structured, one-on-one interviews with PA student volunteers who were enrolled in the spring 2025 hematology module. A pool of interview volunteers was initially identified based on responses to a survey question administered via Qualtrics described in the previous section. After completion of the summative hematology exam, potential interviewees were selected from the cohort of initial volunteers using maximum variation sampling to

ensure inclusion of qualitative data from participants with a variety of exam scores and from participants who both did or did not meet the definition of musically experienced (Creswell & Poth, 2018).

Selected students received an email invitation (Appendix C) to participate in interviews to discuss their experience learning through the song-based instruction method. A consent information sheet was included in this email (Appendix D) in addition to a link to a Google form in which students could choose a date and time to interview. After completing the form, students received electronic calendar invitations including Zoom links via email. The interviews were scheduled within two to four weeks after completion of the hematology module to minimize recall bias, an error in memory of a past event which can be diminished by ensuring a recall period which is proximal to the exposure of interest (Althubaiti, 2016).

I developed interview questions (Appendix I) based on published best practices for writing successful interview protocols (Jacob & Furgerson, 2012). Questions were written with the intention of eliciting data from interview participants which would directly address research question two. Question topics included overall impressions of the module, impressions of the included songs, how songs were utilized and engaged with outside of class and while taking the assessment, perceptions of familiar versus novel melodies on learning, and musical experience.

The first two interviews with students from the spring 2025 hematology module cohort were utilized to pilot test the interview questions. The interview protocol was reviewed before and after the pilot interviews to ensure relevant data collection. Interviews were conducted virtually via Zoom (Version 5.17.11). The Zoom software

was utilized for audio recording of interviews and to generate transcripts. I reviewed recordings and transcripts after each interview to ensure accuracy of the automatic transcription and adjusted them as needed.

Audio recordings of participants were obtained as part of the qualitative interview process to assist with automatic generation of transcripts by the Zoom software platform. Completed transcripts were labeled with the same unique identifier code that was utilized for quantitative data collection. Recordings were deleted/destroyed as soon as transcripts were generated and labeled. Transcripts were kept in a password protected Box folder separate from the code key.

Data Analysis

Quantitative

Quantitative analysis was performed in IBM SPSS Statistics (Version 27). All students who completed the 2024 or 2025 hematology module were included in the quantitative arm of the study. Demographic profiles of each class (age, gender, race/ethnicity) were described. Information about musical experience (experience with formal singing, playing an instrument, and ability to read music) within the spring 2025 cohort was also described. Summative examination scores were analyzed retrospectively for both the control and intervention groups. Kuder-Richardson (KR-20) reliability coefficients were automatically calculated for each administration of the summative examination by the ExamSoft software program (ExamSoft Worldwide, Inc., 2025). Descriptive statistics (means and standard deviations) were calculated for examination scores of both the control and intervention groups.

The primary analysis used independent samples *t*-test to evaluate if there was a statistically significant difference in examination mean scores between the control and intervention groups at an alpha level of 0.05. Effect sizes were also calculated using Cohen's *d*. The independent samples *t*-test was an appropriate choice because it tests differences between means from two independent samples (Howell, 2017). Several assumptions needed to be met including that the independent variable consisted of two independent groups (spring 2024 cohort and spring 2025 cohort), the observations within each group were independent, and the dependent variable (exam scores) was measured on a continuous scale. Data were screened for outliers by comparing box plots. The assumption of normality was tested by analyzing for a non-significant result in the Shapiro-Wilk test. The assumption of homogeneity of variance was tested by analyzing for a non-significant result based on Levene's Test of Equality of Error Variances (Howell, 2017). The independent samples *t*-test has been shown to be robust to violations of the assumptions of normality and homogeneity of variance when samples sizes in groups are greater than or equal to 30 (Pagano, 2009).

In addition to the primary analysis, several subanalyses were conducted using data collected from the intervention group to more fully examine certain aspects of the song-based intervention. Because these subanalyses were exploratory in nature and not the primary focus of the study, power calculations were not performed, effect sizes were not calculated, and they were not included as research questions. The first subanalysis evaluated for significant differences in means between examination items covering topics included in the song lyrics and topics not included in song lyrics. A second subanalysis evaluated for a significant difference in means between the examination items covering

topics included in songs with familiar melodies versus examination items covering topics included in songs with novel melodies. A third subanalysis evaluated for a significant difference in means between students who met the definition of "musical experience" as previously described and those who did not.

To determine whether the independent samples *t*-test could be applied to these subanalyses, assumption testing was performed including screening data for outliers, normality, and homogeneity of variance as described in the previous paragraph. With sample sizes in subanalyses expected to be less than 30, the non-parametric Mann-Whitney *U* test was used instead for the analysis when there were extreme violations of the assumptions of normality or homogeneity of variance or when there were numerous significant outliers (Pagano, 2009).

Qualitative

Employing thematic analysis (Creswell & Poth, 2018), I read interview transcripts in their entirety several times while memoing initial thoughts and emergent ideas regarding transcripts as a whole. I engaged in reflexivity during this process by considering my biases and assumptions (Lincoln & Guba, 1985). Transcripts then underwent first cycle coding using both descriptive and in vivo coding methods. A codebook was maintained which included lists of codes with descriptions. First cycle codes were analyzed and then underwent second cycle coding using an axial coding method. Axial codes from second cycle coding were then further condensed into sub-themes and themes (Saldana, 2013). Verbatim quotes from transcripts which were illustrative of themes were highlighted.

A committee member with expertise in qualitative methods reviewed my work after completing coding of the first two interviews to ensure correct data analysis technique before proceeding to analyze the complete data set. A total of 11 interviews were conducted, at which point thematic saturation was confirmed (Creswell & Poth, 2018). NVivo software was utilized to manage qualitative data. The embedded mixed methods design of this study was carried through the interpretation of results, with the qualitative findings used to explain the quantitative results with greater breadth and depth.

Researcher's Positionality

In qualitative research, it is important that the qualitative researcher position themselves "in relation to the context and setting of the research" and "actively report their values and biases as well as the value-laden nature of information gathered from the field" (Creswell & Poth, 2018, p. 21). In the next sections of this chapter, I describe my role within the context of the study and how my interpretation of results may be biased by certain aspects of my identity. I also describe the pragmatist worldview which serves as a philosophical foundation for this study.

Researcher's Role

I have been a PA for over a decade and have been working full-time as a PA educator for six years. In my current role as an associate professor of public health and community medicine, I teach foundational medical knowledge to first year PA students. I am one of eight core faculty members in a relatively small PA program which matriculates 50 students each year. I serve as an academic advisor to approximately eight students in each class and develop close mentoring relationships with these students. The

natural fondness which I develop toward the students in the program biases me and compels me to teach in a way which is not simply effective, but which is engaging and enriching. My fondness toward students is often reciprocated back to me and so I often feel that students are motivated to do well in my classes at least partly due to the mutually warm and respectful teacher-student relationship that I aim to cultivate. These relationships could not be controlled for in this study and may have impacted both quantitative and qualitative data.

I am also a mother to two young children. Music and songs are ever present in my household, and I have marveled at my children learning language and basic facts about the world through simple songs over the past decade. This has certainly influenced my teaching methods and is likely the truest fountainhead of inspiration for this study and likely biased me toward the assumption that song-based instruction would improve knowledge acquisition and retention not just for children, but for PA students as well. This had the potential to bias my qualitative data analysis.

Worldview

The philosophical foundation of this study is pragmatism. Pragmatism "focuses on the consequences of research, on the primary importance of the question asked rather than the methods, and on the use of multiple methods of data collection" (Creswell & Plano Clark, 2018, p. 450). It assumes that "both the mind-independent physical world and the constructed social and psychological world exist, and the reality is complex and multiple" (Shan, 2022, p. 3). Pragmatism is a common worldview upon which mixed methods studies are built, as it allows for researchers to consider the value and validity that both quantitative and qualitative methods can provide when approaching a research question. This study aimed to provide a quantitative, objective analysis of how song-

based instruction impacts knowledge acquisition while also exploring the qualitative, subjective experience of how song-based instruction influences retention. A pragmatist worldview allows that both methods not only can generate true conclusions, but that the conclusions are likely truer when considered together rather than separately. Additionally, pragmatism focuses on practical applications of research in the real world (Creswell & Plano Clark, 2018), which makes it particularly apt for the applied educational research focus of this study.

Trustworthiness

Trustworthiness is a concept within qualitative research which describes characteristics of a study such that it is "worth paying attention to, worth taking account of" (Lincoln & Guba, 1985, p. 290). Lincoln and Guba (1985) defined four key aspects of trustworthiness: credibility that the findings are true, transferability of findings beyond the study conditions, dependability that results are repeatable, and confirmability that the results were obtained neutrally and without bias. This study ensured trustworthiness of the qualitative results by employing techniques to address each of the four aspects outlined by Lincoln and Guba (1985).

Credibility

Credibility of results was built into this study through the mixed method approach, in which qualitative results were triangulated with quantitative results. Additionally, as this research was being conducted as part of a doctoral dissertation, extensive peer debriefing with my committee methodologist occurred which further enhanced credibility by forcing me to address provocative questions about the research, explore developing hypotheses, and to be pushed to consider next steps in analysis (Lincoln & Guba, 1985).

Transferability

Transferability of results in purely qualitative research is often assured through thick, or in-depth, descriptions of phenomena such that a reader can understand the study conditions deeply enough to decide whether the conclusions are applicable to other situations. Transferability is the qualitative equivalent of external validity in quantitative research (Lincoln & Guba, 1985). In this mixed methods study, thick descriptions were utilized where possible and the triangulation of qualitative findings with quantitative data further provided transferability of results.

Dependability

Dependability of results was established through external audits (Lincoln & Guba, 1985). Because this study is being used to fulfill the requirements of a doctoral dissertation, the research process and results were evaluated throughout the duration of the study by the methodologist. Additionally, the qualitative study methods were described in detail to allow "the reader to assess the extent to which proper research practices have been followed" (Shenton, 2004, p. 71).

Confirmability

Confirmability is the qualitative equivalent of objectivity in a study and is the process by which a qualitative researcher establishes "the value of the data" (Creswell & Poth, 2018, p. 255). One way in which confirmability was ensured in this study was in the exercise of reflexivity that I engaged in earlier in this chapter and in which I made clear my positionality and potential bias regarding this study and its outcomes. Triangulation, which was built into this mixed methods study, was another method which increased confirmability by providing more than one data source in the study design.

Ethical Considerations

Approval to conduct this study was obtained from the Tufts University Health Science IRB. Because summative examination scores are recorded as part of normal educational practices and were reviewed retrospectively, the IRB did not require consent from students for inclusion of scores in the primary analysis of this study. However, informed consent was obtained from participants to collect information regarding their musical experience and to use that information in the quantitative subanalysis (Appendix D). Informed consent was also obtained from all interviewees prior to their participation in the qualitative component of this study (Appendix G). It was made clear to all participants that consent could be withdrawn at any time without consequence. Although students, considered a vulnerable population, were the study population for this proposal, the study design was such that the intervention was infused within normal educational practices and presented minimal risk to study participants.

Data were stored in secure folders using the cloud-based storage service Box and were only accessible to me. Unique identifiers for students in both cohorts were created using an online random ID generator. A key which linked unique identifiers to student names was kept by me in a secure electronic Box folder to protect confidentiality of information. Hematology module examination scores for both cohorts and musical experience information for the intervention cohort were added to a spreadsheet using the unique identifiers as it became available. This document was kept in a Box folder separate from the Box folder in which the key was kept.

Student names were collected as part of the musical experience survey. This was necessary to link responses to participant exam scores for purposes of quantitative

subanalysis of whether musical experience influences the effectiveness of song-based instructional techniques. Survey responses with identifying information were destroyed/deleted as soon as data were collected in a de-identified manner by adding it to the spreadsheet with the unique identifier.

Summary

This chapter provided a description of the methodology used to conduct the study. The purpose of this embedded mixed methods study (Creswell & Plano Clark, 2018) was to determine whether song-based instruction impacts medical knowledge acquisition as measured by hematology module summative examination scores in first-year PA students and to explore student perceptions of song-based instruction on their medical knowledge acquisition. Convenience sampling (Creswell & Guetterman, 2019) and maximum variation sampling (Creswell & Plano Clark, 2018) were utilized.

Quantitative data were obtained through summative hematology module exam scores and qualitative data obtained through semi-structured interviews with students from the intervention group. Independent samples *t*-tests were used to analyze quantitative data (Howell, 2017), thematic coding was applied to qualitative data (Creswell & Poth, 2018), and then quantitative results were interpreted through the lens of qualitative findings (Creswell & Plano Clark, 2018). My positionality and worldview as a researcher were candidly outlined, and steps to ensure trustworthiness of results (Lincoln & Guba, 1985) and ethical research practices were described.

CHAPTER 4: FINDINGS

Introduction

This chapter presents the quantitative and qualitative findings of this embedded mixed methods study. These results address how the song-based instructional approach utilized in the hematology module impacted student knowledge acquisition as well as student perceptions of the intervention. This chapter begins by reviewing the research questions and hypotheses. Quantitative results are then presented, including data screening, descriptive demographic data, and inferential statistical analyses of the first research question and its subanalyses. Next, the qualitative interview participants and coding process are described. Qualitative results are then reported by describing the three themes and seven subthemes which address the second research question.

Research Questions and Hypotheses

The research questions and hypotheses for this study are as follows:

RQ1: Is there a difference in hematology module summative exam scores between first-year PA students who participate in song-based instruction and those who do not?

H_0: There is no difference in hematology module summative exam scores between first-year PA students who participate in song-based instruction and those who do not.

H_A: There is a difference in hematology module summative exam scores between first-year PA students who participate in song-based instruction and those who do not.

RQ2: How do students perceive their acquisition of foundational hematology knowledge through song-based instruction?

Data Screening

Quantitative data included examination scores collected from the Examsoft software platform and demographic student data collected from PA program administrative records for students from both the 2024 and 2025 hematology module cohorts. Survey data regarding student musical experience were collected from the 2025 cohort using the Qualtrics survey platform (Qualtrics XM, 2025). Data were screened prior to analysis for inconsistencies, errors, and completeness and were found to be accurate and complete.

Descriptive Statistics

Aggregated demographic data were collected for both the 2024 and 2025 hematology module student cohorts. The average age for both cohorts was 25, with age being slightly more widely distributed in the 2025 cohort (SD = 3.3) than the 2024 cohort (SD = 2.7). Both cohorts were predominantly female, with 82% female students in the 2024 cohort and 74% female students in the 2025 cohort. The majority of students in both cohorts were white (56% in 2024 cohort, 60% in 2025 cohort) with Asian being the next most common race/ethnicity reported (18% in both cohorts). Table 1 presents the demographic characteristics of the students.

Table 1

Demographic Characteristics of Cohorts

	2024 Cohort (Control)		2025 Cohort (Intervention)	
Demographic variable	*n*	%	*n*	%
Gender				
Female	41	82	37	74
Male	9	18	13	26
Race/ethnicity				
White	28	56	30	60
Black	2	4	2	4
Asian	9	18	9	18
Hispanic	5	10	3	6
Multirace	5	10	5	10
Not disclosed	1	2	1	2

Note. $N = 100$ ($n = 50$ for each cohort). Students were on average 25 years old in both cohorts.

In addition to demographic data, students in the intervention group were surveyed regarding their musical experience, with 38 out of 50 students responding (76% response rate). Of the respondents, 25 (66%) reported that they have musical experience. Of those with musical experience, 16 (64%) indicated experience playing a musical instrument, 19 (76%) indicated formal singing experience, and 14 (56%) indicated the ability to read music (Table 2).

Table 2

Results of 2025 (Intervention) Cohort Musical Experience Survey

	2025 Cohort Survey Respondents (n = 38)	
	n	%
Musical experience[a]	25	66
Can play instrument	16	64
Formal singing	19	76
Can read music	14	56

Note. This table reflects the number and percentage of participants answering "yes" to each survey question.

[a] Musical experience defined as ability to play an instrument or formal singing experience.

Descriptive statistics for exam scores revealed that the 2024 cohort (control group) had marginally lower mean scores on the hematology module summative exam (M = 95.36, SD = 3.713) than participants in the 2025 cohort (intervention group) (M = 96.00, SD = 3.854). Scores ranged between 86% to 100% for both cohorts. Table 3 provides the descriptive statistics for the exam scores.

Table 3

Exam Score Descriptive Statistics by Cohort

Cohort	*N*	Range (%)	*M*	*SD*
2024 Cohort (Control)	50	86 – 100	95.36	3.713
2025 Cohort (Intervention)	50	86 – 100	96.00	3.854

Assumption Testing

To address research question one, an independent samples *t*-test was performed to analyze for differences in mean exam scores between the control and intervention cohorts. Prior to performing the *t*-test, assumption testing to analyze data for outliers, normality, and homogeneity of variance was completed. Review of boxplots indicated that there were no data outliers in exam scores for the 2024 cohort. There was one outlier identified in the 2025 cohort (intervention group) exam score data which was an exam score of 86% (Appendix J, Figure J.1). Given that this was the only outlier in this data set and given that the next highest score in this data set was a score of 88%, this data point did not appear aberrant and so was included in the analysis.

Levene's test indicated that the homogeneity of variance assumption was met (p = .698) (Appendix J, Table J.1). The assumption of normality was tested using the Shapiro-Wilk test (Appendix J, Table J.2) and indicated that the data was not normally distributed ($p < .001$). However, the independent samples *t*-test is often robust to violations of normality when sample sizes are greater than 30 (Pagano, 2009), as in this case, and so with an adequate sample size and all other assumptions met, a *t*-test remained the primary analysis method utilized.

Research Question One Results

The difference in means was not statistically significant, $t(98) = -.846$, $p = .400$, 95% CI [-2.142, .545], indicating that the difference in hematology module summative exam scores between first-year PA students who participated in song-based instruction and those who did not was only nominal. See Table 4 for the *t*-test results. Based on these findings, I failed to reject the null hypothesis.

Table 4

Independent Samples t-Test for Equality of Exam Score Means

			Significance	95% Confidence Interval of the Difference		
	t	*df*	Two-sided *p*	Lower	Upper	Cohen's *d*
Exam score	-.846	98	.400	-2.142	.862	-.169

Subanalyses of 2025 Cohort Data

A subanalysis was conducted to determine whether there was a significant difference in mean item performance (measured as percentage of students who answered an item correctly) when comparing exam items testing concepts included in the lyrics of songs and exam items testing concepts not included in songs. Assumption testing to analyze data for outliers, normality, and homogeneity of variance was completed. Review of boxplots (Appendix J, Figure 2.1) indicated two outliers in the items covered by song data. These correlated to the two lowest scoring items in this category (82% and 66% of students answering these items correctly). There was one outlier in the items not covered by song data (82% of students answered this item correctly). These three scores are all well within the range of plausible performance for exam items and so were included in the analysis.

The Shapiro-Wilk test indicated that the assumption of normality was not met ($p < .001$) and the Levene's test indicated that the homogeneity of variance assumption was not met ($p = .023$) (Appendix J, Tables J.3 and J.4). Although parametric tests, such as the independent samples *t*-test, are often robust to violations of normality when sample sizes are greater than 30 (Pagano, 2009), sample sizes in this case were not adequate to overcome the normality and homoscedasticity violations ($n = 21$ items covered by song,

n = 29 items not covered by song) and so the non-parametric Mann-Whitney U test was performed instead. The majority of items on the hematology module exam were not covered by song (n= 29). Items not covered by song (M = 96.27, SD = 3.991) performed marginally better than those covered by song (M = 95.60, SD = 8.401), though there was not a statistically significant difference found between groups (U = 240.000, p = .219). Tables 5 and 6 provide descriptive statistics and Mann-Whitney U test results, respectively.

Table 5

Descriptive Statistics for Percentage of Students Correctly Answering Exam Items Covered by Song and Not Covered by Song

	N	Range (%)	*M* (%)	*SD*
Covered by song	21	66 – 100	95.60	8.401
Not covered by song	29	82 – 100	96.27	3.991

Table 6

Mann-Whitney U-test Results for Exam Items Covered by Song and Not Covered by Song

	% Correct
Mann-Whitney U	240.000
Z	-1.230
Asymp. Sig. (2-tailed)	.219

A second subanalysis was conducted to analyze for significant differences in mean item performance (measured as percentage of students who answered an item correctly) when comparing exam items which assessed concepts included in the lyrics of songs with familiar melodies to exam items included in the lyrics of songs with novel melodies. Assumption testing to analyze data for outliers, normality, and homogeneity of

variance was completed. Review of boxplots (Appendix J, Figure J.3) indicated one outlier in the familiar melody data (82%) and one outlier in the novel melody data (66%). These correlated to the two lowest scoring items in each category and are all well within the range of plausible performance for exam items and so were included in the analysis.

The Shapiro-Wilk test indicated that the assumption of normality was not met ($p < .001$) (Appendix J, Table J.5). The Levene's test indicated that the homogeneity of variance assumption was met ($p = .725$) (Appendix J, Table J.6). Although parametric tests, such as the independent samples *t*-test, are often robust to violations of normality when sample sizes are greater than 30 (Pagano, 2009), sample sizes in this case were not adequate to overcome the normality violation ($n = 6$ items covered in songs with familiar melodies, $n = 15$ items covered in songs with novel melodies) and so the non-parametric Mann-Whitney *U* test was performed instead.

As shown in Table 7, exam items assessing topics covered in songs with familiar melodies ($M = 96.33$, $SD = 7.090$) performed marginally better than items assessing topics covered in songs with novel melodies ($M = 95.29$, $SD = 9.135$), though there was not a statistically significant difference between groups ($U = 40.500$, $p = .894$). Table 8 presents the Mann-Whitney *U* test results.

Table 7

Descriptive Statistics for Percentage of Students Correctly Answering Exam Items Covered by Songs with Familiar and Novel Melodies

	N	Range (%)	*M* (%)	*SD*
Familiar melody	6	82 – 100	96.33	7.090
Novel melody	15	66 – 100	95.29	9.135

Table 8

Mann-Whitney U-test Results for Performance of Exam Items Covered by Songs with Familiar and Novel Melodies

	% Correct
Mann-Whitney U	40.500
Z	-.133
Asymp. Sig. (2-tailed)	.894

A final subanalysis was conducted to analyze for significant differences in exam scores between students with musical ability and students without musical ability. Assumption testing was completed and review of boxplots (Appendix J, Figure J.4) indicated one outlier in the exam scores of musical students (86%) and three outliers in the exam scores of non-musical students (88%, 88%, and 92%). These correlated to the four lowest scores on the exam within this group but are all well within the range of plausible exam scores and so were included in the analysis. The Shapiro-Wilk test indicated that the assumption of normality was not met ($p < .001$) (Appendix J, Table J.7). The Levene's test indicated that the homogeneity of variance assumption was met ($p = .717$) (Appendix J, Table J.8).

Although the independent samples *t*-test is often robust to violations of normality when sample sizes are greater than 30 (Pagano, 2009), sample sizes in this case were not adequate to overcome the normality violation ($n = 25$ students with musical ability, $n = 13$ without) and so the non-parametric Mann-Whitney *U* test was performed instead. There was no statistically significant difference in mean exam scores between groups based on musical experience (Table 9) with the Mann-Whitney *U* test confirming no significant difference in group means ($U = 155.000$, $p = .811$) (Table 10).

Table 9

Exam Score Descriptive Statistics by Musical Experience

	N	Range (%)	*M* (%)	*SD*
Musical	25	86 – 100	95.68	4.190
Not musical	13	88 – 98	95.54	3.755

Table 10

Mann-Whitney U-test Results for Exam Scores by Musical Experience

	Exam Score
Mann-Whitney U	155.000
Z	-.239
Asymp. Sig. (2-tailed)	.811

Research Question Two Results

To answer the second research question, qualitative data were collected from a sample of students in the 2025 cohort through one-on-one, semi-structured interviews. This section first presents a description of the participants in general and the theme development process. This is followed by an in-depth explanation of the three themes and seven subthemes developed during qualitative data analysis and illustrating these themes and subthemes through participant quotes from interview transcripts.

Participants

Eleven participants consented to and participated in qualitative interviews for this study. The mean hematology module exam score for interview participants was 95.8% with a range from 88% to 100%. The mean age of interview participants was 23.7 years old with an age range from 23 to 27. Seven individuals identified as female and four identified as male. All participants described their race as White. Nine of the 11 participants identified themselves as musical based on either formal experience playing

an instrument (n = 7) and/or formal singing experience (n = 6). See Table 11 for the demographic characteristics of participants. To maintain confidentiality, interview participants were assigned the following pseudonyms: Alice, Ben, Chloe, Daphne, Eric, Felix, Greg, Hannah, Iris, Jordan, and Katie.

Table 11

Demographic characteristics of interview participants

Demographic variable	n	%
Gender		
Female	7	64
Male	4	36
Race/ethnicity		
White	11	100
Musical ability?		
Yes	9	82
No	2	18

Theme Development

The data collected during qualitative interviews were analyzed to address the second research question. An inductive analytic approach was employed. Analysis started with immersion in the data through the reading of each interview transcript multiple times while engaging in memoing to record emerging ideas and questions about the data. Transcripts then underwent first cycle coding using both descriptive and in vivo coding methods, resulting in 106 initial codes. First cycle codes were reviewed along with previous memos and were condensed into 23 second cycle codes (Appendix K) using axial coding. I continued to memo during this process of first and second cycle coding.

Upon reviewing the 23 second cycle codes multiple times, considering relationships between them, and reviewing memos, second cycle codes were further

condensed into seven sub-themes: a) Classroom learning impacted by songs in multiple ways, b) Songs utilized as study tools for retention and recall, c) Song melodies mattered for memory, d) Songs were both entertaining and educational, e) Module instruction was engaging and effective, f) Past musical experiences mattered, and g) Songs facilitated connections with self and others. Finally, these seven sub-themes were further condensed into three themes which directly address research question two: 1) Songs supported knowledge acquisition in multiple ways, 2) Songs positively impacted the learning experience, and 3) Songs facilitated reflection and connection. The theme development process and the final themes and subthemes are presented in Figures 2 and 3, respectively.

Figure 2

Theme Development Process

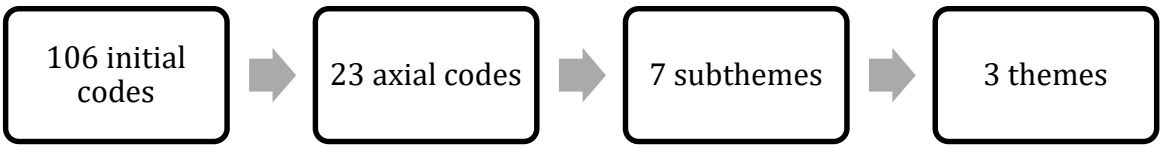
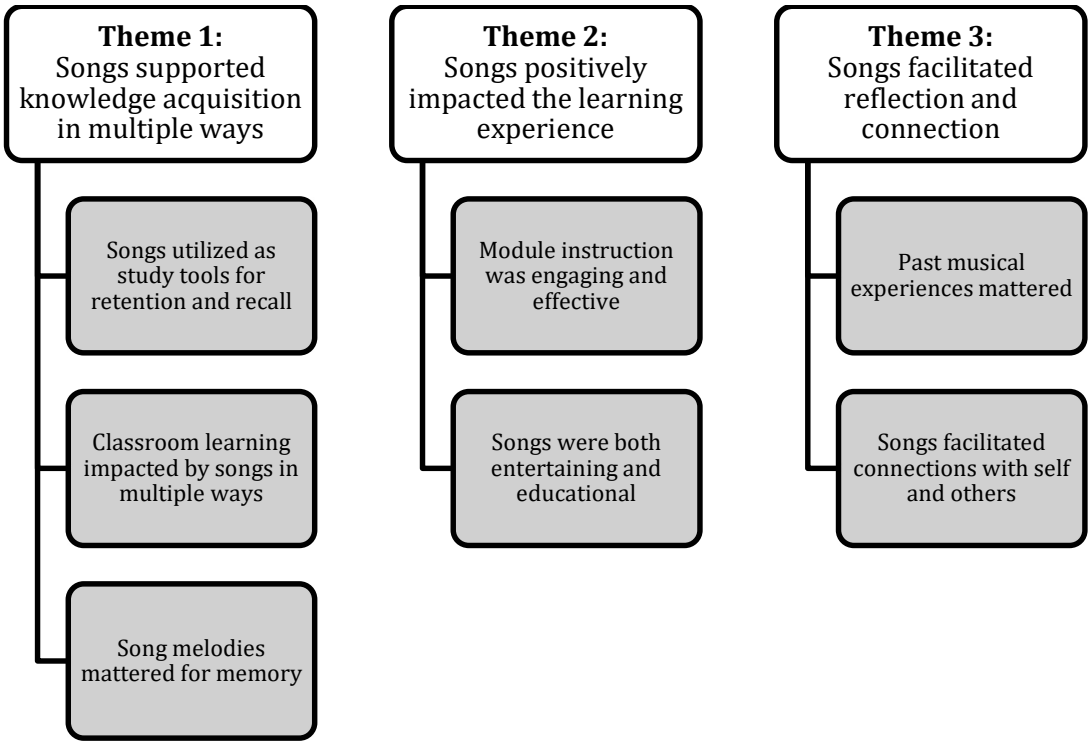


Figure 3

Themes and Subthemes



Theme 1: Songs Supported Knowledge Acquisition in Multiple Ways

Participants spoke about multiple ways that the inclusion of songs with content-specific lyrics in the hematology module impacted their learning process during classroom lecture sessions, served as tools which were utilized to enhance retention of information during studying, and facilitated recall of information during the examination. The quality of melody tied to content-specific lyrics was perceived to impact the usefulness of a song for retention and recall of information. This theme includes three subthemes: classroom learning impacted by songs in multiple ways, songs utilized as study tools for retention and recall, and song melodies mattered for memory.

Classroom Learning Impacted by Songs in Multiple Ways

This subtheme speaks to the impacts that the song-based instructional method had on the active *process* of acquiring foundational hematology knowledge during classroom lectures. All participants spoke about the song lyrics acting as indicators of important information in lectures. Ben described the module in general as "dense" but pointed out that, "Obviously, it's impossible to get all the information that we were talking about into a song. But I think it was nice to go over, like, the main points." Highlighting key concepts and facts in each lecture was found to be valuable and useful. As Hannah explained:

> It definitely helped my learning because it knocked out a lot of the…I don't know how to put this, but the, the words that we didn't need to know. It knocked those out and just broke it down into simple terms, using simple words really quickly, which I really like because that's something that I, when I study, I have to do a lot of myself…it's easier when you, who, who knows the information that we need to know, does it for us so that we can tease out the, that we don't have to waste time teasing out those details. And we can instead just focus on that key stuff from the, the get go.

Key concepts were not only signaled to students by the content of the lyrics, but also by the rhyming and verse structure of the songs in some cases. This aspect of the songs supported organization of information and also cued students into important points. For example, Iris stated:

> 'Cause like with med phys [medical physiology course]…right now, I feel like I have the facts. But then there was a question like, oh, what happens in the small

> intestine? I had no clue because I can't, I haven't pieced everything back to a whole yet, like, where it happens. But heme [the hematology module] was structured in a way where it's very easy for me to do that, which is something that has been harder for me in other classes…and I think it was partially the songs, kind of just like seeing, okay, when this lyric ended or stanza…ended and there was a new stanza, I don't know, it was easy to see, okay. Change in location, change in topic, which is really helpful.

The songs written for the module included content-specific lyrics pertaining to an important concept or concept from each lecture and were performed live during lectures by me. The actual performance of the songs during class provided a built-in space for review and repetition of key concepts, which students perceived as supportive of learning. Greg described the impact of the songs by saying, "Like, I think they, like, they really were so…I think you took a lot of care, and how you created the lyrics to the songs, and so that it was very relevant and applicable." Reflecting on the impact of the songs in general, Chloe noted:

> Oftentimes I find myself, like, during class, like, this is not specific to hematology, but in general I don't, like, remember things, like, right away that maybe, like, other students do. So, like, it only sticks in my head when I review it, like, one or two times after class again. So, I think the songs did help, like, it, just, you know, like, the main ideas were, like, put on the screen again, and you sang them so, like, it was nice to hear the main ideas again.

Students perceived that the songs also functioned as a broad summarizing mechanism for the important concepts covered in the module. Felix noted that, "It is very helpful to, like,

assign a one word or a small phrase to the condition, which is what a lot of those songs did." Ben echoed the same sentiment, saying:

> I think that they definitely were, like, a nice, like, recap for what we went over during class. Like, obviously, it's impossible to get all the information that we were talking about into a song. But I think it was nice to go over, like, the main points, as far as, like, this is what each one looks like. For, like, the, the transfusion reactions, that one was cool because it was like, oh, if you have this going on, give them this. If you have this going on, give them this. Probably doesn't, you can't go into, like, all of the details of that stuff. But it was definitely a cool point.

Beyond acquisition of the factual "key points", the songs were also felt to positively impact more general conceptual understanding and to provide clarity of muddy points which remained after the initial presentation of information during lecture. Katie reflected, "I feel like it was, like, the concepts that I was most confused about, or, like, that relying on the songs would help me the most." Alice also spoke about her use of the songs to clarify confusing concepts as well as to provide a broad overview of lecture content:

> Like, I thought that each song really captured, like, a big picture thing of each lecture and that was helpful…and then I could dive into kind of the muddier parts of things that I may or may not have, like, kind of understood and memorized. But I felt like each song really, like, I'll just be repetitive, just captured like big picture parts of the lecture, and I felt, like, they were a good starting point.

Songs Utilized as Study Tools for Retention and Recall

This subtheme speaks to the ways that participants utilized the songs to retain information while studying information outside of class and preparing for the examination, as well as the utility of songs as recall tools while taking the examination. Several participants explicitly described using the songs for examination studying purposes. For example, Katie commented:

> I found myself listening to them, like, after class when I was studying, but then also, like, right before the exam. I was, like, listening to them like a lot more, and I feel like it just helped sink in things like subconsciously kind of, I don't know, like it was stuck in my head, even when I didn't, like, expect it to be kind of, but I thought it was awesome. I really liked it.

Some participants further described using the songs as a tool for studying while engaging in other activities, like exercise or commuting, and appreciated the flexibility this provided to study in situations or at times when they might otherwise not have access to study materials. As Greg explained:

> It, like, allowed me to study in a slightly different setting than I normally do. So I, I take the train every day, and I generally don't really like to study on the train. But I found I could, like, listen to the songs on the train. And so that was one thing to, like, oh, like, I'm taking this time and making it productive in a way which felt nice.

Daphne listened to the songs during her commute and also at home, stating that, “But when I went home as studying, I would, like, listen to it in the background, or I'd listen to it, like, on the train.”

Songs were made available on the learning management system as .mp4 files which included the audio of songs and a visual slide with lyrics (Appendix I). Like Greg and Daphne, Eric described using the .mp4 files to study outside of class, saying, “Yeah, it was the .mp4s that were on Canvas. And honestly, I played them on the T going to and from school, which was perfect. It was super accessible.” In addition to simply listening to songs, students described that multimedia engagement with the songs (seeing the song lyrics while listening to the songs) felt like it enhanced the retention of information included in the content-specific lyrics. Greg described:

> I saw, like, I could both hear what the melody was, I could see where it was, like, on the page, because I would, like, watch the videos along with the recordings of of, of the ones that you had posted of you singing them before. I really remembered what the lyrics were.

Chloe, Eric, and Jordan denied using the songs as a study tool while still expressing appreciation for their role in the classroom learning process. Chloe noted that, “I didn't use it as a study tool for the exam, but I think it was a good tool with, like, you know, these are the main ideas. Like, this is what is important,” while Eric shared:

> When I went to go and actually study and learn the material, I think I wanted to get a deeper understanding of, kind of the concepts that the song hit on as opposed to just, like, kind of those buzzwords, like, these are, like, the high yield concepts. And so, I think I dug a little bit deeper into each one of those, and because of that I didn't, like, rely on the songs as much to, to go in and actually learn and study the material. Just because, to be honest, it's not, like, super how my brain works.

Most participants denied using the songs during the examination specifically as a recall, or mnemonic, mechanism. Instead, they described that using the songs as study tools while preparing for the exam helped them to acquire the knowledge in an enduring way so that they did not need to rely on the song as a mnemonic to recall information. Alice explained:

> When the first song was introduced, I originally thought, like, oh, like, maybe I can sing them during the exam, and it will help me. I actually found that, like during the exam, I was just so locked in, and I didn't do that at all, but it helped me study, like, the big picture things.

Hannah had a similar experience to Alice, stating that, "When I take exams, I'm, like, anxious, so I don't really think about other things… I felt like, I grasp it all really well from knowing the songs and using those as like initial study materials."

However, a few students did mention using the songs to aid in the recall information while taking the examination. Daphne remembered using a song to answer a question about diagnostic criteria for multiple myeloma, stating "Yeah, I remember, like, the CRAB criteria, because I remember going through, like, oh, like C's for this, R's for, like, this." Alice also remembered using a song during the exam:

> There was one that I thought about, and it helped me answer a question…I wanna say it was the hemolysis song and the reticulocyte count that helped me. The reticulocyte count helped me answer, like, a question, like, a question about, like, what type of anemia is this specifically. That's something I can remember.

Song Melodies Mattered for Memory

This subtheme described how students perceived that the familiarity or novelty of a song's melody impacted knowledge acquisition. Most participants discussed that songs with familiar melodies seemed to be more effective than those with novel melodies. One of the reasons mentioned was that the familiar melody helped to anchor the new, lyrical information to the previously learned tune. Hannah explained:

> The songs with the melodies that I was more familiar with were more helpful in learning the, the actual words to them because there is something to, like, go along with it. So when I was reading the lyrics over, even when I wasn't listening to the version of you singing it, I was able to, like, tie it together in my own head a little bit more, and, like, not, like, understand it a little bit more myself, if that makes sense.

Felix explained why he thought a familiar melody makes it easier to remember lyrics, saying that, "Even if you can't remember, like, like, at least you'll remember the, the rhythm of the song, and then you have to supplement, like, what words fit into that."

A second reason that students perceived songs with familiar melodies to be more effective was that the familiar melody allowed students to more quickly engage with the songs when they were presented during the classroom lecture. As Greg put it:

> I think one of the, one of the really great things about this was when you got people to, like, when there was sort of a, a chorus that would repeat and you would get people to sing it with you in class, like, the second or third time it came around. And I feel like that was really engaging, and something I haven't really

> seen in the classroom before, and I feel like that's only possible if it is a melody that people are already familiar with.

In comparison, Daphne attributed a melody's upbeat tempo and instrumental accompaniment to increased participation more so than to the familiarity of its melody.

> I really like the microcytic anemia song (novel melody). I don't know why that one's, like, my favorite. Maybe, like, cause it, like, you were playing the ukulele in that one. I know that. And also, I think, like, I don't know if it was, like, the key, was it? It was just very, like, upbeat and catchy.

Participants who concluded that they personally did not perceive a difference in the songs based on melody familiarity still reflected on the potential for familiar melodies to support retention of knowledge more easily than novel melodies. For example, Katie said:

> I don't think so truthfully. I feel like the only thing that I sometimes would do is like I would know the tune, but I wouldn't know the words, and I was, like, this isn't quite very helpful for me. But that was just me, like, forgetting it. So maybe the ones that were, like, more, like of a tune that we already knew, I knew the tune already so that I could, like, learn the words instead of, like, having to learn both. But I don't think it was super different, comparatively.

Theme 2: Songs Positively Impacted the Learning Experience

Independent of the utility of songs as tools for knowledge acquisition, students spoke broadly and enthusiastically about the ways that the songs positively impacted their sense of engagement during lectures, the overall classroom climate, and their impressions

of the module in general. The subthemes for this theme include songs were both entertaining and educational and module instruction was engaging and effective.

Songs Were Both Entertaining and Educational

Several interview participants specifically mentioned that the inclusion of songs in lectures provided entertainment in addition to being supportive of learning. This provided a welcome contrast to other courses in the curriculum with traditional lecture-based styles. Chloe noted:

> "All, like, our classes are the same kind of style. It's all, like, you know, the professor is lecturing, and we're listening. And so, I think the music component really brought some, like, life to the class, and, like, allowed us to just, like, have fun more which is, like, a nice way to embed, I don't know, just, like, a different environment in the class."

Jordan explained how increased engagement in class made her learning feel more effortless than in other classes:

> Yes, so I felt like in other classes I kind of need to put in more effort to really learn the material, because it's like, it is spoken to me, and then, like, I'm listening. But I feel like I need to do more active things to get it to stick. Whereas in the hematology module it felt like the songs, like, it didn't take more effort for me to really engage. Like, I'm always paying attention in my classes, but it felt like it was easier to pay attention when we were doing something like that.

A specific aspect of the song-based instruction which students appreciated was the function of the songs as an interruption from the traditional lecture-based style employed within the hematology module itself. The performance of the songs created a

natural break in lecture and shift in energy which students felt increased their ability to focus during class. For example, Ben explained:

> I feel like everybody kind of loved that part because in lectures, obviously, people start to lose focus. So, I think the songs kind of reeled people back in and made people, like, re-engage a little bit just because it wasn't so, like, you know, melodramatic reading off the slides and stuff like that. It just, kinda, it brings it off the page.

Similarly, Daphne said: "I thought it was also fun, because it, like, broke up like a normal lecture…I feel like sometimes when you do different things that, like, helps, like, you stay more engaged throughout the rest of the class as well, because it kind of wakes up your mind."

Students, while appreciating the utility of the songs to support their knowledge acquisition, also generally felt that the song-based instructional method created a learning environment which was fun and happy and made them look forward to the class. Hannah described:

> I love the songs a lot. They made me really happy. And so not only, like, were they, they helpful because they tell you, like the most important parts of what the song is about, but it also just like brought up the energy in the room and made it, made it a bit happier being there which I really liked. And so I think that yeah, that was my…I loved it.

Eric agreed, saying, "I loved it. I think that it was something that I looked forward to every single class we had…I thought it was both kind of, like, entertain, entertaining and educational."

Module Instruction was Engaging and Effective

Interview participants perceived that, in general, I was effective at presenting lecture material in a way which helped students learn the complex topics within the hematology module. They described me as being facile at presenting difficult concepts in an understandable way. Hannah commented:

> I felt as if it was a very complicated subject that you made learning a lot easier, and by breaking everything down and putting things into more simple terms. And so it seemed like there was a lot of stuff, obviously a lot of different diagnoses that were confusing, and, and everything. But you did a great job of, like, helping tell me what the key details was between it in a way that was easy for me to understand, because it's just our, we, we didn't really know anything about it beforehand.

Ben agreed with Hannah, saying, “I think that the way that stuff was presented made it pretty easy, like, especially the differences between, like, B12 deficiency and folate deficiency are, like, the first one that comes to mind. As far as, like, I feel, like, that one was laid out really well.”

Participants commented specifically that the song-based instructional method resulted in a positive overall impression of the quality of the instruction and the effort I put into the construction of the course. Ben noted:

> “It showed that you put in a lot of effort into your preparation, too. You know, like, above and beyond everybody else. Like, writing, like, was it six or eight songs?...I think that as a class, we definitely recognize how, how cool that was and how unique that was to, kind of, your teaching.”

Greg further explained:

> I think people really liked that you had taken the time to do that, too. Like, I think there's, there's another level of, like, how do you, how do you demonstrate and show to a class that you're like engaged in the material and engaged in, like, teaching? And so, I think, sort of, like, regardless of what the actual project is, I thought that was, like, it came across as, like, it came across well, to the class.

Participants also felt positively in general about song-based instruction and suggested that it could even be applied more widely in other modules or courses. Alice said:

> I think the people that sit around me are kind of annoyed, like, I'm still singing these songs. Like, they just are so, like, they just stick. And it's important information, like, it's the, I feel like, it's the most important information from each lecture. So I, I think it's so helpful. I think it should be in every class, in every course.

Theme 3: Songs Facilitated Reflection and Connection

Participants reflected throughout the interviews on how their identity as musical or non-musical and their past experiences with music impacted their perception of the song-based instructional method. Participants connected their experience with song-based instruction in the hematology module to past song-based instructional experiences. Participants also described the songs as points of connection with other health professions learners. The subthemes for this theme include past musical experiences mattered and songs facilitated connections with self and others.

Past Musical Experiences Mattered

Most of the interview participants identified themselves as musical based on formal experiences playing an instrument or singing as previously described. Students felt that this aspect of their identities positively impacted their perception of the song-based instructional method by making them more inclined to listen to the songs outside of class and to remember the songs more quickly. For example, Daphne noted, "I do think my musical background made me more inclined to try and study with the songs and allowed me to catch onto the melodies quicker." Alice agreed, stating:

> I definitely think being a musical person helped me when it came to learning through the hematology songs. I usually pick up lyrics and melodies pretty quickly, which I think gave me a bit of an advantage. It made it easier for me to remember the material and stay engaged. I can't really say how it would be for someone who isn't into music, but overall, I found the songs helpful and easy to catch on to.

Musically-identifying participants also commented that learning through the songs made them feel that they were using a "different part" of their brain than they usually used when studying. Greg described this by saying, "music hits your brain in a different way." Katie explained:

> I feel like when you've, like, been accustomed to playing music and, like, hearing music, that side of your brain is, like, already, I don't know…like, well formed. I don't know if that's the right way to say it. But, like, for me, I do feel, like, when I'm listening to music or, like, playing music, it's using a different part of my

> brain that's like…I don't know if other people experience that, too. I don't know if I'm making any sense either, but, like, I think that it's more subconscious in a way.

Eric and Iris indicated that they were non-musical, meaning they had no formal experience with singing or playing a musical instrument. Iris explained that her lack of musical experience likely did impact her experience with song-based instruction:

> I think that if, I think it would make sense that if I was more musical, I think they would have helped even more, honestly. Just, I think it would be…It's easy to remember, if you like, kind of…I've always been really bad at, like, remembering, kind of, songs. Even the songs I listen to every day, at least, to listen to before every game, I still don't know all the words, so I think for someone who's more musically inclined, it would definitely be a lot more helpful.

Eric, who generally felt positively about the inclusion of song-based instruction in the module, pointed out that lack of musical experience does not necessarily equate to lack of musical appreciation:

> I, like, I enjoy listening to music. Like, if I'm going to school, I've got music on. If I'm going grocery shopping, I've got music on, on my airpods, and so I, like, engage in music in in that way. And so I don't, I'm not, I guess, to be, I'm not 100% sure whether or not my, my lack of any musical training changed the outcome of me using the songs or not.

Songs Facilitated Connections with Self and Others

Alice, Greg, and Daphne recalled past childhood experiences in which they learned material through songs and that they were still able to recall this learned information as adults. These memories were referenced by participants as supportive of

their perceptions of song-based instruction as an effective learning tool. Alice recalled, “When I was young, and I was learning about, like, tadpoles in, like, 3rd grade, I could not memorize how, like, the process of tadpole to frog. And my mom and I, we made a song of how to memorize the cycle of the tadpole, and, like, we still talk about it to this day.” Greg shared his own anecdote:

> These experiences remind me of a social studies teacher, geography teacher I had in middle school who, we had little songs to learn the countries, like, of the world. And, like, I can still remember, like, the, the Middle East one, like, could, like, rattle off 15 countries in, in the Middle East because of that song, and, like, I was talking to my friend about this, like, a few years ago, and he was, like, oh, yeah. Like, we still both know the song and so I think there, there is that, like, longitudinal, like, not just my relationship with music is longitudinal, but that melodies stick in your head in a different way than just, than just sort of data does.

Participants also remarked that the hematology songs were shared among both the cohort of students enrolled in the hematology module and with friends engaged in other health professions education programs. Within the cohort, Ben disclosed that, “In one of our group chats with a few people in class, we have like a song of the day we'll send sometimes. Your songs were in there for a few when we were studying.” Beyond the cohort, Jordan recalled:

> There was one specific time, though, that I hung out with a few of my friends that are pretty into music, like, they did like acapella in college and stuff like that. And they're also going to medical school. They're going to medical school and I

showed them all the songs because I thought it was really cool, and they thought it was really cool.

Summary

This chapter presented the results of the quantitative and qualitative analyses in this embedded mixed methods study to understand the impact of song-based instruction on hematology knowledge acquisition. The quantitative analysis showed that there was no statistically significant difference ($p = .400$) in hematology module exam scores between control ($M = 95.36$, $SD = 3.713$) and intervention ($M = 96.00$, $SD = 3.854$) cohorts. Quantitative subanalyses similarly resulted in no statistically significant differences in exam scores in the intervention cohort for test items covered in songs versus items not ($p = .219$), items taught by songs with familiar versus novel melodies ($p = .894$), and within the cohort based on musical ability ($p = .811$). Qualitative interview participants and the qualitative coding process was described. The three qualitative themes (Songs supported knowledge acquisition in multiple ways, Songs positively impacted the learning experience, and Songs facilitated reflection and connection) were described along with their subthemes and illustrative quotes provided.

CHAPTER 5: DISCUSSION

Introduction

This study utilized an embedded mixed methods approach to quantitatively determine the impact of song-based instruction on examination scores within a hematology module delivered to first semester PA students and to qualitatively explore how students perceived the influence of song-based instruction on their acquisition of foundational hematology knowledge. This chapter will interpret the findings in the context of existing literature and information processing theory as well as discuss their practical, empirical, and theoretical implications. Limitations of the study will be discussed, areas for future research will be recommended, and conclusions will be presented.

Interpretation of the Findings

In the quantitative arm of the study, mean hematology module examination scores were nominally higher in the intervention group (M = 96.00, SD = 3.85) when compared to the control group (M = 95.36, SD = 3.71), though this difference was not statistically significant (p = .400). A series of subanalyses resulted in no statistically significant differences in scores based on whether test item topics were covered in songs, whether test item topics were covered in songs with familiar versus novel melodies, and within the cohort based on musical experience.

However, scores were nominally higher when familiar melodies (M = 96.33, SD = 7.09) were used versus novel melodies (M = 95.29, SD = 9.14) and for musically experienced students (M = 95.68, SD = 4.19) versus those who were musically inexperienced (M = 95.54, SD = 3.76). In contrast to the non-significant quantitative

results, the qualitative analysis revealed that students nevertheless perceived the song-based instructional intervention as supportive of their knowledge acquisition, as positively impacting their learning experience, and as a facilitator of reflection and connection with their own experiences and the experiences of others.

The finding of nominally higher mean examination scores in the intervention group, though not statistically significant, does suggest a positive impact of the song-based instructional method on knowledge acquisition. The practical significance of this finding comes into clearer focus when interpreted through the lens of the qualitative findings, in which students perceived positive impacts of the intervention on their learning. These positive findings are consistent with studies from the psychology literature in which song-based instruction was found to support retention and recall of learned information (Chazin & Neuschatz, 1990; Ginsborg & Sloboda, 2007; Ludke et al., 2014; Lummis et al., 2017; McElhinney & Annett, 1996; Rainey & Larsen, 2002; Wallace, 1994).

It is worth mentioning that the lack of statistical significance regarding the impact of a song-based educational approach is not a completely unprecedented finding in the literature. Racette and Peretz (2007) found no advantage to song-based instruction in an experimental study involving a sample of French-speaking undergraduate student participants who were asked to learn and, later, either recite or sing back the lyrics to a French folk song after first learning the lyrics in either a spoken or sung format. They used this result to argue against the value of song-based teaching methods despite previous studies with positive results. Though my study findings may, at face value, seem to support the conclusion of Racette and Peretz (2007), there are important differences in

our studies worth nothing. First, in my study students were, of course, not asked to demonstrate their mastery of foundational hematology information by singing it. The song lyrics presented in my study were content-specific and situated within a larger curriculum intended to educate students about general medicine, not lyrics to a random folk song as in the Racette and Peretz (2007) study. Additionally, there was a nominal increase in performance in the intervention group in this study and the qualitative findings provide further evidence that the song-based instruction had impacts on learning beyond those which were quantitatively measured.

The lack of statistical significance in quantitative findings in this study may be reflective of a cohort effect. The mean undergraduate GPA of the control cohort was 3.8 on a 4.0 scale and the mean undergraduate GPA of the intervention cohort was 3.9. In contrast, a recent national survey showed that the mean undergraduate GPA of PA students in the Unites States is 3.6 (Physician Assistant Education Association, 2024a). The student participants in this study have an extraordinarily high track record of academic excellence and so the quantitative measures in this study may not have been adequately sensitive to measure the true impact of the song-based intervention in the intervention group.

It is possible that the slightly higher mean undergraduate GPA in the intervention group compared to the control group was congruent with the nominally higher mean examination score in the intervention group. However, in contrast to the quantitative results, the qualitative arm of the study clearly shows that students perceived an impact from the inclusion of songs, congruent with the findings of Chan (2014) that songs helped students with learning and memorization of content. This further validates the

importance of the mixed methods approach to this study to more sensitively capture the effect of the independent variable on the dependent variable.

It is also possible that the lack of significant quantitative findings is related to a delay in time between the intervention and the examination. In this study, the dependent variable was measured via a knowledge assessment which was administered one week after the date of the final module lecture and five weeks after the date of the first lecture. Chazin and Neuschatz (1990) found that song-based instruction was effective in aiding recall of learned information in the short term but not after one week. It is possible that this phenomenon may be reflected in the quantitative findings of this study, although Chazin and Neuschatz (1990) used songs to communicate non-contextually relevant information to their study participants, whereas the song lyrics in this study were intentionally written to match content being taught within the hematology module itself. Additionally, in this study exposure to songs outside of class was not controlled for. Several interview participants described using the songs outside of class and listening to them repeatedly, indicating that some students were exposed to the songs multiple times and more proximally to the date of the examination than the initial presentation within the lecture session. This limits the ability to interpret the temporality of the exposure to the results in this study.

Of further note regarding temporality, Calvert and Tart (1993) found that adult students were able to recall facts (the Preamble of the United States Constitution) initially learned through songs during childhood, decades earlier. Though contradictory to the findings of Chazin and Neuschatz (1990), the qualitative data from my study support the phenomenon described by Calvert and Tart (1993), with a few interview participants

sharing similar anecdotes of remembering information learned through childhood songs. This may, again, be related to the contextual relevance of information being taught though the song-based approach, as those who listened to the Preamble song as a child likely did so in the context of classroom study of United States history. This supports that song-based teaching methods may, indeed, be useful for very long-term recall of learned information, especially when that information is relevant to the learner, and further highlights the value that the qualitative component of this study brings in interpreting the quantitative results.

A question which was explored both quantitatively and qualitatively in this study regarded whether lyrics set to a familiar melody provided a superior learning tool versus lyrics set to an unfamiliar melody. Though not statistically significant, there was a nominal increase in performance on assessment items which tested concepts covered in songs with familiar melodies versus unfamiliar melodies. This implies that content specific lyrics attached to familiar melodies may better facilitate retention and recall of lyrical information than novel melodies. The qualitative results further suggested that songs with familiar melodies were perceived as easier to recall and with students describing the familiar melodies acted as cues for the associated content-specific lyrical knowledge. This is congruent with the findings of Wallace (1994) and McElhinney and Annett (1996), who concluded that melodies do, indeed, matter and are the keys to a song's mnemonic value.

Another question which was explored both quantitatively and qualitatively regarded the impact of one's musical experience on the utility of the songs as a learning tool. Again, there was a nominal increase in the examination scores of students with

musical experience in the intervention cohort versus those without musical experience, implying that song-based instructional methods would be most impactful in educational settings in which a majority of students have musical experience. This is in contrast to the findings of Wallace (1994), who found an advantage to song-based instruction even when controlling for musical ability, but in congruence with Kilgour et al. (2000) and Lummis et al. (2017), who found that musical experience was advantageous. The qualitative findings in this study meaningfully contribute to the literature on this point by corroborating that musically experienced learners do likely have at least a perceived advantage over those who are not musically experienced based on their more effortless understanding of and interest in music.

Importantly, as was pointed out by one interview participant, lack of musical experience does not equate to lack of musical appreciation. Two of the major qualitative themes in this study were that songs positively impacted the learning experience and that songs facilitated reflection and connection. The ability to metacognitively reflect is a key component of the information processing model of self-regulated learning developed by Winne and Hadwin (1998), in which reflective metacognition supports learning through increased focus on important information as well as improved connections between working and long-term memory. Connection with others is another key component of learning according to Vygotsky (1978), who described that learning and meaning first occur through interactions with other people before an individual internalizes and learns new information themselves. Even if musically inexperienced students are at a disadvantage regarding the use of songs as study tools, through facilitated reflection and

connection there is still theoretical value in the utilization of a song-based instructional method for these students.

Information processing theory provides the primary theoretical framework for interpretation of the findings of this study. Miller (1956) was the first to propose that humans process information in a manner similar to a computer, and this process was further described by Atkinson and Shiffrin (1968) as occurring in three distinct stages in the sensory register, short-term (or working) memory, and long-term memory. In previous studies, the mnemonic value of song-based instruction has been attributed to its facilitation of information encoding and organization in long-term memory (Tamminen et al., 2017) and its function as a cue when information is later retrieved (Wallace, 1994).

The qualitative findings of this study provide further insight into how the song-based instructional method impacted the processing of the content-specific lyrical information and significantly contributed to the theoretical understanding of this topic. Miller (1956) wrote famously about the limits of short-term memory processing to seven (plus or minus two) units of information at once. One major way that participants in the qualitative interviews noted that the songs supported their learning was by identifying key concepts within lecture content. Learning within the context of a PA program, like many other health professions programs, involves the acquisition of incredible amounts of information in a short period of time and has been described with the idiom “drinking from a fire hose” (Jacques, 2004). In this study, the content included within songs written by me, the songwriter and instructor, was interpreted as a signal to students of which content was most important and relevant within each lecture. Viewed through a theoretical lens, it could be argued that the curation of important information in the song

lyrics made it more likely that this information was attended to in the sensory register and transferred to the short-term memory.

Information which is attended to and which makes its way into the short-term memory must then be rehearsed, or repeated, before being transferred to long-term memory. Information which is not rehearsed is lost and not remembered (Atkinson & Shiffrin, 1968). Participants in this study described the songs as rehearsal mechanisms both through in class performances of the songs and through relistening to recordings of the songs outside of class. In this way, songs provided additional tools for rehearsal of information and increased the likelihood that information would be encoded and retained.

Another interesting point which came out of the qualitative analysis and which connects to information processing theory is that students utilized both the audio and audiovisual recordings of songs as study tools. This allowed students to study while doing non-academic activities like commuting or exercising and was perceived as an advantageous aspect of the intervention. Hermanns et al. (2012), in their study using content-specific songs to teach pharmacology concepts to nursing students, similarly described that students utilized recordings of songs to study while completing other tasks. It was also noted that being able to see the song lyrics while listening to the audio of the song augmented retention of the information being studied.

The value of audiovisual educational tools is supported by multimedia learning theory, which explains that multimedia approaches to instruction cause learners to process both sounds and images in the working memory simultaneously, to integrate those sounds and words with previously learned material, and to encode the new knowledge in long-term memory (Mayer, 2008). Several students in this study perceived

that seeing the song lyrics while listening to the songs supported their learning and memory of the songs, and this perception is supported by multimedia learning theory. Multimedia learning can enhance information processing through both facilitating organization of learned information in working memory and its encoding and connection to previously learned knowledge in long-term memory (Lee et al., 2006). Multimedia approaches to instruction are thought to be especially useful for high achieving students and for tasks which require quick filtering of information (Dillon & Gabbard, 1998), like as in this study and in many health professions educational settings.

Within information processing theory, the transfer of rehearsed information from the short-term memory into the long-term memory, where it is then organized and connected to existing information, is known as encoding (Atkinson & Shiffrin, 1968). Tamminen et al. (2017) proposed that musical instructional methods likely enhance encoding through the activation of broad cognitive networks, allowing newly learned information to be better connected to previously learned information. Several interview participants in this study described that relistening to the songs as a method of studying helped them to retain the content-specific lyrical information in a way which felt more enduring than when studying conventionally, which implies that the songs were supportive of encoding as Tamminen et al. (2017) suggested. The work of Calvert and Tart (1993) suggested that listening to song recordings repeatedly improves long-term recall of words. Providing audiovisual recordings of songs may have facilitated repetition of exposure and, therefore, supported knowledge acquisition in this study, though frequency of use was not measured.

Information which is encoded is only helpful if it can be successfully retrieved, or recalled, at appropriate times. Wallace (1994) suggested that when information is learned through content-specific lyrics tied to a melody, the melody itself can act as a cue which aids in the retrieval of the associated information. Some participants in this study did report actively recalling a certain song when taking the hematology examination and that this helped them access the information needed to answer a certain question, which supports that the melody may have functioned as a cue to the retrieval of the associated lyrical information.

An aspect of the song-based instructional method which came through clearly in the qualitative results is the positive impact of this method on students' sense of engagement, joy, and connection within the classroom and with the material being taught. Beyond a mere tool for knowledge acquisition, bringing song and performance into the classroom correlated with students feeling happy about the module in general, satisfied with the instructional methods, interested in the content, and excited to share about their experiences within the cohort and beyond. The joyful aspect of using songs to engagingly teach science-based material was also noted in McLachlin's (2009) study in which he used songs to teach biochemistry concepts to undergraduate students in a large lecture setting and Chan's (2014) study in which she asked nursing students to write and perform songs about epilepsy. While the quantitative aspect of the study did not show a significant impact on learning due to the song-based intervention as measured by examination scores, the qualitative aspect unmasks a more complete picture of the impact of the intervention on the overall experience of learning throughout the module.

Implications

The findings of this study, which explored the impact of a song-based instructional approach on knowledge acquisition within a PA education context, have a number of important implications. Empirically, these findings support previous studies in the psychology literature which have found that learning information as content-specific lyrics tied to a melody can positively impact retention and recall of that information (Chazin & Neuschatz, 1990; Ginsborg & Sloboda, 2007; Ludke et al., 2014; Lummis et al., 2017; McElhinney & Annett, 1996; Rainey & Larsen, 2002; Wallace, 1994). However, there have previously been no studies which used mixed-methodology to more deeply and broadly explore this phenomenon. The mixed-methodology used within this study is, thus, groundbreaking in that it explores this area of research using novel methodology which helps to qualify these previous positive quantitative findings while also providing a qualitative context to studies in which a song advantage was not demonstrated (Racette & Peretz, 2007).

Although only a nominal increase in learning was quantitatively shown in the intervention group in this study, the qualitative themes suggest that learning was positively impacted by the intervention in numerous ways. The importance of the qualitative component of this study in holistically understanding the impact of the independent variable on the dependent variable further highlights the importance, and dearth, of more diverse research methods within health professions education, and PA education specifically, to evaluate innovative educational approaches.

Practically, though there was only a nominal increase in the exam scores between control and intervention cohorts, there is qualitative evidence to suggest that employing a

song-based instructional strategy within a PA educational context effects knowledge acquisition in multiple ways, positively impacts the learning experience, and facilitates reflection and connection with self and others. When creating songs with content-specific lyrics, setting lyrics to familiar melodies is likely a more effective approach than using novel melodies (Wallace, 1994). Additionally, choosing familiar melodies which are simple will more likely support knowledge acquisition than choosing complex melodies (Ludke et al., 2014).

Another practical implication is to ensure that song lyrics are germane and connected to the topic being taught (Rainey & Larsen, 2002). Teaching a musically experienced cohort may enhance the efficacy of the intervention (Kilgour et al., 2000; Lummis et al., 2017) but is not essential for song-based instruction as either an effective (Wallace, 1994) or enjoyable approach. Health professions educators may consider incorporating songs with content-specific lyrics related to the content being taught within their teaching regardless of the musical ability within the class. Lastly, providing learners with audiovisual recordings of the songs affords them a multimedia learning tool which supports the integration and organization of learned content (Mayer, 2008).

Theoretically, this study provides evidence that a song-based approach to instruction, especially when content-specific lyrics are written intentionally to represent important content within a learning module, impacts learning. This supports the theory of information processing by providing a mechanism by which extraneous cognitive load, the less important details from a lecture, can be decreased by focusing attention on the most important details included in song lyrics (Sweller, 2011). This may have allowed for more efficient processing and encoding of information from working memory to long-

term memory and facilitating retention and recall of information (Ashcraft & Radvansky, 2014; Atkinson & Shiffrin, 1968; Miller, 1956).

This study also demonstrated that song-based instruction, when audio and/or audiovisual recordings of songs are made available for review outside of the learning context, provides a multimedia study tool which can be supportive of learning. This further supports information processing theory and, specifically, the theory of multimedia learning which posits that information presented both aurally and visually can facilitate encoding of information (Lee et al., 2006; Mayer, 2008). However, instructors must take care in this aspect of the intervention, as it is known that multimedia approaches can also overwhelm working memory and interfere with information processing if not carefully curated (Mayer et al., 1999).

Limitations of the Study

This study is not without limitations. In the quantitative aspect of the study, the use of a non-validated measurement tool (the hematology module examination) presents a threat to internal validity. This validity threat, however, was likely minimized in some part by the construction of the exam by me, an experienced PA educator with doctoral training in education, and the regular review of the module and its assessments by the program's director of didactic education as well as regular review by a larger, internal programmatic curriculum committee with diverse membership. Additionally, the content validity of the assessment is supported by its alignment with module learning objectives as well as congruence with the PANCE hematology blueprint (Appendix E). The overall assessment score mean was quite high for both the control ($M = 95.36$, $SD = 3.713$) and intervention ($M = 96.00$, $SD = 3.854$) cohorts with fairly narrow score ranges (86%-100%

for both cohorts) which likely interfered with the ability for this study to truly discriminate between differences between cohorts.

Regarding reliability of the assessment instrument, a Kuder-Richardson reliability coefficient (KR-20) was calculated for each administration of the examination (0.44 in control group, 0.54 in intervention group). KR-20 scores above 0.7 are generally considered to be acceptable regarding internal consistency (Wombacher, 2017). With KR-20 scores lower than 0.7 for both administrations of the examination, this may call into question the reliability of the hematology module assessment tool and be considered a limitation. However, KR-20 scores decrease as the number of items answered correctly by all test takers increase (Cortina, 1993). In this case, the low KR-20 scores were likely driven by the high overall scores on the examination in both groups. Given the foundational nature of this module, it was the expectation that many test takers should have mastered the content being tested in order to progress forward within the program, and so an argument can be made that a lower KR-20 is expected and, even, appropriate in this context.

Additionally, the small, single site sample limited the statistical power of the study and calls into question the generalizability of results to other PA programs or more broadly to other health professions education contexts. In addition to impacts of sample size on power and generalizability within the study, the convenience sampling method in which the 2024 cohort was the de facto control group and the 2025 cohort the de facto intervention group in the study may have impacted results due to unforeseen confounding. For instance, factors such as differences in admissions processes between years and differences in course instruction outside of the hematology module were not

measured or factored into results. Furthermore, the effect of mean undergraduate GPA in both control and intervention cohorts being higher than the mean undergraduate GPA of PA students in a national sample further calls external validity of findings into question. However, according to Mayer (2008), situating educational research in an authentic learning situation, as was done in this study, allows for the investigation of both theoretical and practical research questions and so these dual gains may justify negative impacts of the sampling methodology on external validity.

The songs which were written for this study were all relatively short and each focused only on one key concept within hematology. Because of this, this study may not have captured the true impact of song-based instruction compared to a study in which all content was represented in the lyrics of a song. Although this was at least partially addressed through the subanalysis which tested differences in performance on assessment items testing concepts covered in song versus not, the limited exposure to the intervention in this study is a noted limitation. Moreover, the frequency of access to audiovisual song recordings was not measured in this study and so it is not possible to determine whether frequency or infrequency of exposure to the recordings impacted the study results.

In the qualitative aspect of the study, the researcher's role as both qualitative interviewer and module instructor may have biased participant responses. Participants may have self-censored negative comments as to not offend or negatively impact their relationship with the interviewer/instructor. Additionally, as in any qualitative research study, there is inherent subjectivity to the data and its analysis. Because interviewees volunteered to participate, the interview pool may have been skewed toward the overrepresentation of students who felt positively toward the intervention, biasing the

results. However, the mixed-methodology of this study supports validity despite these limitations for both quantitative and qualitative aspects of the study.

Recommendations for Future Research

While positive impacts of song-based instruction were found in the qualitative analysis within this study, the insignificant findings in the quantitative analysis make it clear that further research is needed to fully understand the impact of a song-based instructional approach in PA education. A longitudinal study in which songs are integrated in several courses, or even throughout a curriculum, would allow for a more robust investigation of this concept. Revisiting the intervention cohort at future points in time to reassess knowledge of hematology concepts or perceptions of the song-based instruction could further inform understanding of the longer-term impacts of the intervention.

Furthermore, the quantitative findings in this study were likely impacted by the inclusion of small, single site cohorts which are academically stronger than the average PA student and the use of a non-validated measurement tool which was likely not sensitive enough to detect changes in the dependent variable between cohorts. Repeating this study with a larger sample which is more representative of the national PA student population and measuring the dependent variable with a validated instrument would allow for a more methodologically sound analysis of the first research question and its subquestions.

Despite the quantitative limitations, the qualitative analysis provided rich data which supports that a song-based instructional approach can be an innovative and impactful tool for the PA educator. The review of literature in this study shows, however,

that there is a need for additional research into the impact of song-based instructional methods within PA education. There is also opportunity for this instructional method to be employed and studied within other health professions disciplines.

The mixed methods approach to this study allowed for a holistic investigation of this topic and research questions. While the primary construct investigated in this study was knowledge acquisition, the qualitative results indicated that the song-based instructional method impacted other important aspects of the learning experience, such as engagement, belonging, and joy. Moreover, the findings of this study indicate that the song-based intervention may impact learning through facilitation of self-reflection and connection with others which are not fully captured within the theoretical framework of information processing. Future research could more fully and explicitly explore the impact of a song-based intervention on these other types of outcomes, potentially employing validated survey tools in a pre- and post-intervention design or utilizing alternate theoretical frameworks to more broadly and validly further this investigation.

Conclusion

The purpose of this embedded mixed-methods study was to a) determine whether song-based instruction effects foundational hematology knowledge acquisition as measured by hematology module summative exam scores for first-year PA students and to b) explore student perceptions of song-based instruction on their medical knowledge acquisition. The study found no statistically significant quantitative differences between exam scores in the control and intervention groups. Likewise, there were no statistically significant differences in performance between exam items covering topics included in the song lyrics and topics not included in song lyrics, between the assessment items

covering topics included in songs with familiar melodies versus assessment items covering topics included in songs with novel melodies, and between students who were identified as musically experienced and those were not. However, the qualitative component of the study unmasked effects of the intervention which were not measured quantitatively including that the songs supported knowledge acquisition in multiple ways, positively impacted the learning experience, and facilitated reflection and connection.

For PA educators, and perhaps health professions educators more broadly, a song-based instructional approach has the potential to be an impactful intervention to support the acquisition of foundational knowledge in learners. Though this study does not present evidence that song-based instruction impacts examination grades with statistical significance, it does present compelling evidence that songs which are thoughtfully created and curated within a curriculum can act as multimedia study tools which support learning and create an engaging, joyful, and meaningful learning environment.

APPENDIX A: Email Script for Survey (Initial) Recruitment

Subject Line: Invitation to Complete Research Survey

Dear students,

I am working on a PhD in health professions education at the University of Maryland, Baltimore. For my dissertation project, I am doing a research study to see how using songs in my teaching affects how you learn. The songs that I have included in our hematology lectures are part of this study. I am inviting you to take part in one part of this study in which I will look at how your musical background affects learning through song-based teaching methods.

If you agree to participate, you will fill out a short survey about your musical experience and if you would like to join an interview about your thoughts on learning with songs. The survey should take no more than 5-10 minutes to complete.

Joining this study is voluntary and will not affect your grade in the Internal Medicine I course or your status in the PA program. While you will need to share your name in the survey, your answers will be marked with a code and kept separate from your personal information. Your participation will help us learn more about this new way of teaching!

If you would like to take part, please read the attached consent information sheet and then follow this link to the survey. If you have questions, please reply to this email.

Thank you for considering!

Rayne Loder, MHS, PA-C (she/her/hers)
Clinical Associate Professor
Director of Interprofessional Education
Physician Assistant Program
Tufts University School of Medicine
[redacted]
Boston, MA 02111
[redacted]

APPENDIX B: Consent Information Sheet for Musical Experience Survey

Consent Version: 1/27/2025 A

Consent Information Sheet

The Effect of Song-based Instruction on First-Year Physician Assistant Students' Knowledge Acquisition

You are invited to participate in a research study being conducted by Rayne Loder from Tufts University School of Medicine (TUSM) Physician Assistant (PA) Program. This study is for students like you who are enrolled in the Internal Medicine I course (PA 203) during the spring of 2025.

If you choose to join the study, you will be asked to complete a survey. This survey will take about 5 minutes and will help us understand how using songs in teaching affects how PA students learn.

Your participation in this study is completely voluntary. You can decide to participate or not to participate and this will not impact your status as a student at Tufts University. You can skip questions that you do not want to answer, or stop participating at any time without any consequences.

There is a risk that your private information could be seen by people outside of the research team. To reduce this risk, your survey answers will be marked with a code and kept separate from your personal information. Your answers and personal information will not be shared with anyone outside the research team.

While there are no direct benefits for you from participating in this study, your involvement may help others by improving the way PA programs teach using new and innovative methods. You will not be paid for your participation.

If you have questions, concerns, or complaints, or think the research has hurt you, please contact Rayne Loder at rayne.loder@tufts.edu.

If you have questions about your rights as a research study subject, call the Tufts Medical Center and Tufts University Health Sciences Institutional Review Board (IRB) at (617) 636-7512. This study has been reviewed by the Tufts Health Sciences IRB.

APPENDIX C: Email Script for Interview Recruitment

Subject Line: Invitation to Participate in a Qualitative Research Interview

Dear student,

Thank you for showing interest in joining a qualitative interview about your experience with song-based learning in the hematology module. I am working on a PhD in health professions education at the University of Maryland, Baltimore. For my research project, I am studying how song-based instruction affects learning in PA education. By interviewing students in this class, I hope to better understand how using songs changed your learning experience.

If you decide to participate, you will schedule a Zoom interview at a time that works for you. During the interview, I will ask about your thoughts and experiences with the songs in your hematology module.

Taking part in this study is voluntary and will in no way impact your grade in the Internal Medicine I course or your position in the PA program. The interview will be recorded to create transcripts automatically, but these recordings will be deleted after the transcripts are made. The transcripts will not have any personal information that can identify you. Your participation will help to contribute to research on this creative teaching method!

If you are willing to participate, please read the attached information consent sheet and then use this link to choose a time for the interview. Please reply to this email with any questions!

Thank you for considering!

Rayne Loder, MHS, PA-C (she/her/hers)
Clinical Associate Professor
Director of Interprofessional Education
Physician Assistant Program
Tufts University School of Medicine
[redacted]
Boston, MA 02111
[redacted]

APPENDIX D: Consent Information Sheet for Qualitative Interviews

Consent Version: 1/27/2025 B

Consent Information Sheet

The Effect of Song-based Instruction on First-Year Physician Assistant Students' Knowledge Acquisition

You are invited to participate in a research study being conducted by Rayne Loder from Tufts University School of Medicine (TUSM) Physician Assistant (PA) Program. This invitation is for students like you who were enrolled in the spring 2025 Internal Medicine I course (PA 203).

If you choose to participate, you will have a virtual interview on Zoom. This interview will help us learn more about your experiences and thoughts on learning hematology through song-based teaching. The interview will last about 30-45 minutes.

Your participation in this study is completely voluntary. You can choose to join or not to participate and this decision will not affect your status as a student at Tufts University. You can also skip any questions that you do not want to answer, or stop participating at any time without any consequences.

There is a risk that your personal information could be seen by someone not involved in the research. To reduce this risk, we will delete the recordings of the interviews as soon as we create transcripts. We will ask you to keep your camera off, so that only audio is recorded. Transcripts will have codes instead of your name, and they will be kept separate from your personal details. Some quotes from your interview may be included in research reports, but they will not include any information that could identify you.

There are no direct benefits to you from taking part in this research. We cannot promise any benefits to others from your taking part in this research. However, your involvement could help others understand and improve teaching methods in PA programs.

You will not be paid for your participation.

If you have questions, concerns, or complaints, or think the research has hurt you, please contact Rayne Loder at rayne.loder@tufts.edu.

If you have questions about your rights as a research study subject, call the Tufts Medical Center and Tufts University Health Sciences Institutional Review Board (IRB) at (617) 636-7512. This study has been reviewed by the Tufts Health Sciences IRB.

APPENDIX E: PANCE Hematologic System Content Blueprint

- Autoimmune disorders
- Coagulation disorders
    - Clotting factor disorders
    - Thrombocytopenias
- Cytopenias
    - Anemia
    - Leukopenia
- Cytoses
    - Polycythemia
    - Thrombocytosis
- Hereditary disorders
    - G6PD deficiency
    - Hemochromatosis
    - Sickle cell disease
    - Thalassemia
- Immunologic disorders
- Neoplasms, premalignancies, and malignancies
    - Acute/chronic lymphocytic leukemia
    - Acute/chronic myelogenous leukemia
    - Lymphoma
    - Multiple myeloma
    - Myelodysplasia
- Transfusion reaction

APPENDIX F: Hematology Module Songs

URL to audiovideo YouTube song recordings:
https://youtube.com/playlist?list=PLhpViK6jhReKHHstd8U8I842jWBFIVEJv&si=zXm_CCjukDOxuakB

QR code which links to audiovideo YouTube song recordings:

"The White Blood Cell Song"

To the tune of "Twinkle Twinkle Little Star"

Verse 1:

White blood cells, how I love you
Please keep me safe from COVID and flu!
Neutrophils they lead the charge
Because their count is very large;
Eosinophils keep worms at bay
But sometimes they bring aller-jay!

Verse 2:

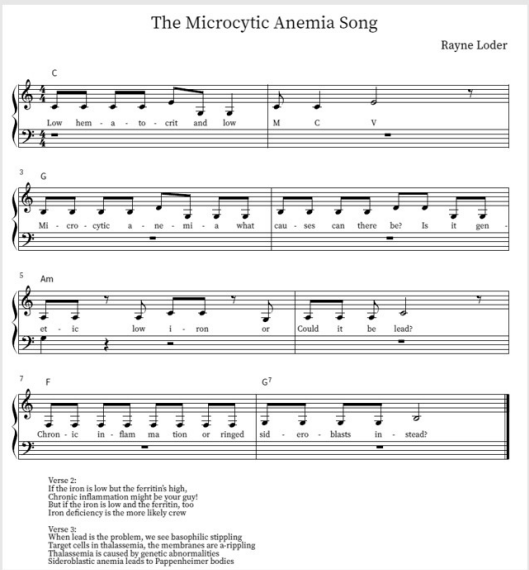
Basophils are purplish blue
They release histamine and heparin, too
Monocytes are quite voluminous
As macrophages they fulfill their usefulness
White blood cells, how I love you
Please keep me safe from COVID and flu!

The Microcytic Anemia Song

Low hematocrit and low MCV,
Microcytic anemias, what causes can there be?
Is it genetic, low iron, or could it be lead?
Chronic inflammation or ringed sideroblasts instead?

If the iron is low but the ferritin's high,
Chronic inflammation might be your guy!
But if the iron is low and the ferritin too
Iron deficiency is the more likely crew

When lead is the problem, we see basophilic stippling
Target cells in thalassemia, the membranes are a-rippling
Thalassemia is caused by genetic abnormalities
Sideroblastic anemia leads to Pappenheimer bodies

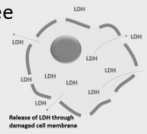


The Hemolysis Lab Findings Song

(To the tune of "Oh, Suzanna!")

Verse 1:

When the red cells start to break apart
Their pieces floating free
The LDH will start to rise
A lab sign we can see

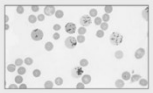


Chorus:

Oh, hemolysis!
RBCs destroyed
LDH, bili, retic counts up
Haptoglobin is employed

Verse 2:

The bilirubin's climbing
Indirect version is found
The bone marrow is working hard
Retics are all around!

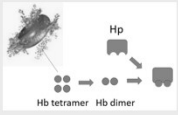


Chorus:

Oh, hemolysis!
RBCs destroyed
LDH, bili, retic counts up
Haptoglobin is employed

Verse 3:

Haptoglobin's busy binding
All the hemoglobin that it can
So when it drops, we know for sure
Hemolysis is at hand!



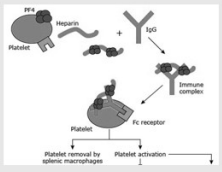
Chorus:

Oh, hemolysis!
RBCs destroyed
LDH, bili, retic counts up
Haptoglobin is employed

The Thrombocytopenia Blues

Verse 1:

A7 If you were recently sick and platelet
D7 numbers are slacking,
A7 It could be ITP—your antibodies self-
D7 attacking
A7 You're heparin naïve and now you find
D7 yourself clotting,
A7 It could be HIT, platelets and PF4 a-plotting



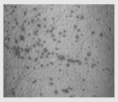
Verse 2:

Bloody diarrhea in kids should make us worry
That HUS could lead to kidney injury
In TTP, we see platelets go wild
They tear up RBCs, ADAMTS13 is exiled.

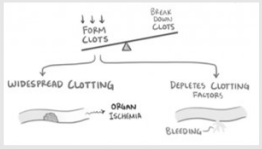
Chorus:

D7 A7
ITP – HIT – HUS – TTP
E7 A7
I've got the thrombocytopenia blues

Verse 3:

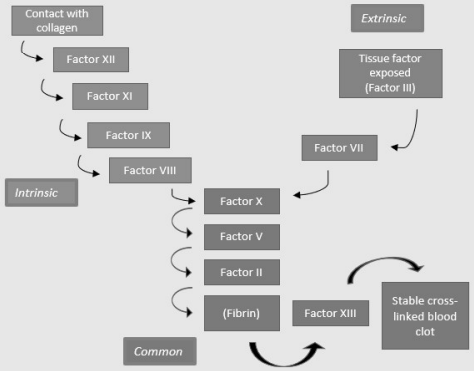


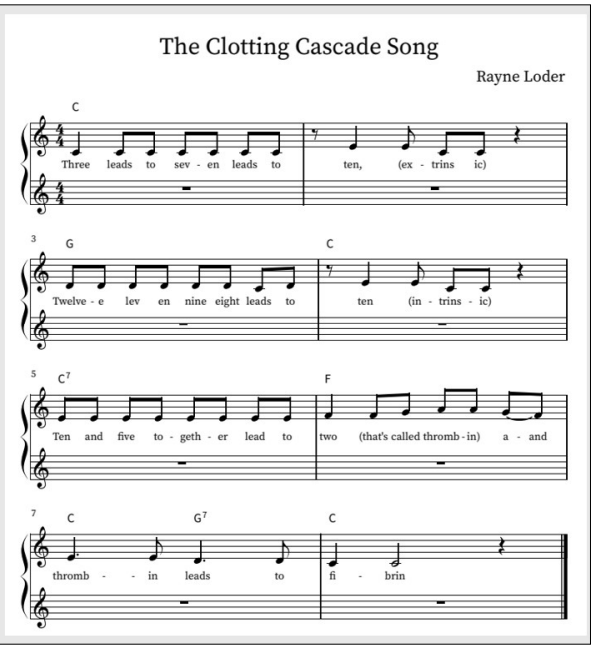
And one more thing, we haven't talked about it yet
But DIC is usually part of this set
In DIC, coagulation's diffuse,
It burns through RBCs and platelets til the blood it starts to ooze



"The Clotting Cascade Song"

3 leads to 7 leads to 10 (extrinsic)
12, 11, 9, 8 leads to 10 (intrinsic)
10 and 5 together lead to 2 (that's called thrombin)
And thrombin leads to fibrin!





The Transfusion Reactions Song

(To the tune of "She'll Be Coming 'Round the Mountain")

Verse 1 – Anaphylactic
If they're wheezing and they're swelling, stop the flow!
Give them epi, Benadryl, and don't go slow!
It's an allergy so rare, IgA's not even there,
It is anaphylaxis, and now you know!

Verse 2 – Hemolytic
If they're shaking, turning yellow, & in pain
It's a mismatch, the wrong blood type was obtained!
Stop transfusion right away, flush with fluids—don't delay!
RBCs are hemolyzing in the veins

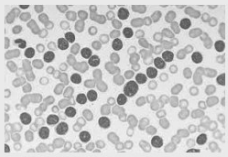
Verse 3 – Febrile Non-Hemolytic
If a fever starts to climb but they feel fine
It's from cytokines—it happens all the time!
Give acetaminophen, next time leukoradiation,
It's just a little fever, not a crime!

Verse 4 – Septic
If they spike a fever and don't feel so hot
And their BP drops like crazy—sounds like shock
Get a culture, start IVs, give antibiotics please,
This is sepsis, and the situation's fraught

Verse 5 – TACO
If their lungs are fluid filled and BP's high
They got too much volume too fast, that is why!
They just need some diuretics, TACO's real, now don't forget it!
Slow the rate and they'll recover by and by!

Verse 6 – TRALI
If they crash, O2 and BP are too low
But their heart is doing fine, that's not TACO
Neutrophils they were a-baited, anti-HLA activated
TRALI's deadly, treat it fast, prestissimo!

"The Leukemia Song"



Lots of blasts and Auer Rods

Likely AML, good odds

Leukemia in a kid

Think ALL, heaven forbid

Philadelphia chromosome

CML is that syndrome

Treat CML with imatinib

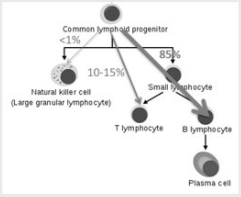
Watch in APML for hemorrhage

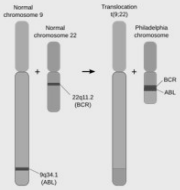
Then there's just one left to spell

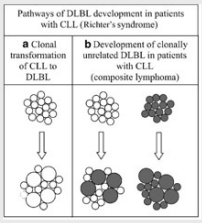
This one goes by CLL

High white cells for very long

Unless Richter's makes everything go wrong







"The Multiple Myeloma Song"

(To the tune of "Mary Had a Little Lamb")

If plasma cells are out of touch

Make immunoglobulins too much

The **CRAB** criteria help us see

If myeloma it might be

C for hypercalcemia

Bones, stones, groans etcetera

R for renal injury

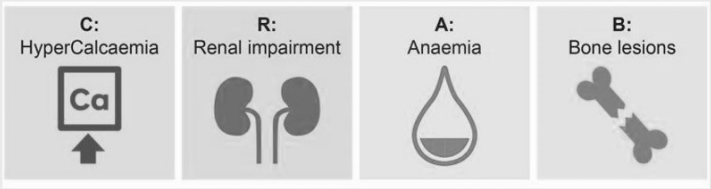
Urine full of Bence-Jones proteins

Anemia can also be

From that monoclonal gammopathy

Bony lytic lesions on xray

Give myeloma away



APPENDIX G: Lectures, Song Topics, and Assessment Items Covered by Songs

Lecture Topic	Song Topic	Assessment Items Covered by Songs (total for lecture)
Lecture 1: **Introduction to Hematology and The Complete Blood Count**	Types of white blood cells	1 exam item (6 total)
Lecture 2: **Anemias Part 1 (Hypoproliferative Anemias)**	Differential Diagnosis of Microcytic Anemia	2 exam items (7 total)
Lecture 3: **Anemias Part 2 (Hemoglobinopathies & Hemolytic Anemias)**	Diagnosing hemolysis	2 exam items (8 total)
Lecture 4: **Platelet disorders**	Thrombocytopenias	4 exam questions (7 total)
Lecture 5: **Disorders of coagulation**	The clotting cascade	4 exam questions (7 total)
Lecture 6: **Tranfusion Reactions, Polycythemia Vera, Aplastic Anemia, WBC Derangements**	Transfusion reactions	1 exam question (5 total)
Lecture 7: **Leukemias**	Leukemias	5 exam questions (5 total)
Lecture 8: **Lymphomas and Multiple Myeloma**	Multiple myeloma	2 exam questions (5 total)

APPENDIX H: Musical Experience Survey and Interview Interest Question

1. Please indicate your name.
2. Have you ever participated in a singing activity (such as a choir or chorus)?
    a. If so, for how many years?
3. Can you play a musical instrument?
    a. If so, for how many years have you played?
4. Can you read music?
5. Are you interested in participating in an interview about your experience as a student in the hematology module?

APPENDIX I: Qualitative Interview Protocol

Thank you so much for agreeing to participate in this interview. I am working on a PhD in health professions education at the University of Maryland, Baltimore. For my research project, I am studying how song-based instruction affects learning in PA education. By interviewing students in this class, I hope to better understand how using songs changed your learning experience. In qualitative research, your words are the data, so please feel free to be open and honest when answering my questions. How you respond will not impact your standing in the hematology module, the IM course, or within the program.

Do you have any questions for me before we start?

1. First, let me just ask you some basic demographic questions:
    a. What is your age?
    b. How do you describe your gender?
    c. How would you describe your race and/or ethnicity?
2. Great, thank you. To start, let me just ask what were your overall impressions of the hematology module in general?
3. Each hematology lecture included a song. What were your impressions of that?
4. How do you think the songs in this module impacted your learning, if at all?
5. Did you engage with the songs outside of the lecture time?
    a. If so, can you describe what that looked like? When and how did you use the songs?
        i. Did you access them via Canvas, via YouTube, just as slides within lectures, etcetera?
6. Did you think of any of the songs while taking the examination?
    a. If so, can you remember which ones and whether it was helpful to you?
7. Tell me about any differences you perceived between the songs which had familiar melodies and the songs which did not have familiar melodies.
8. Do you consider yourself "musical"?
    a. If so, how are you musical? If not, why not?
    b. Do you think this aspect of your identity had anything to do with the way that the songs in the hematology module impacted your learning and, if so, how?
9. Is there anything else you think it is important to say about how the inclusion of songs in the hematology module impacted your learning?

Thank you so much for your time! If you have questions, concerns, or complaints, or think the research has hurt you, please contact me by email at [redacted]

If you have questions about your rights as a research study subject, you can contact the Tufts Medical Center and Tufts University Health Sciences Institutional Review Board (IRB).

APPENDIX J: Assumption Testing

Figure J.1

Boxplot to assess for outliers in primary analysis data

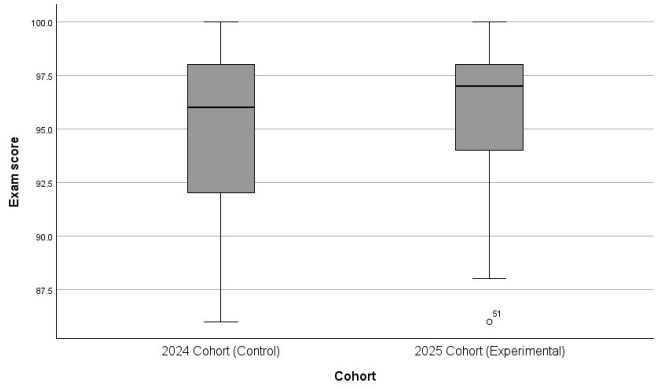


Table J.1

Tests of normality in primary analysis data

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Exam score	.224	100	<.001	.877	100	<.001

a. Lilliefors Significance Correction

Table J.2

Primary Analysis Data - Levene's Test of Equality of Error Variances[a,b]

		Levene Statistic	df1	df2	Sig.
Exam score	Based on Mean	.151	1	98	.698
	Based on Median	.000	1	98	1.000
	Based on Median and with adjusted df	.000	1	96.439	1.000
	Based on trimmed mean	.070	1	98	.792

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Dependent variable: Exam score

b. Design: Intercept + Cohort

Figure J.2

Boxplot to assess for outliers in items covered in song vs. not covered in song subanalysis

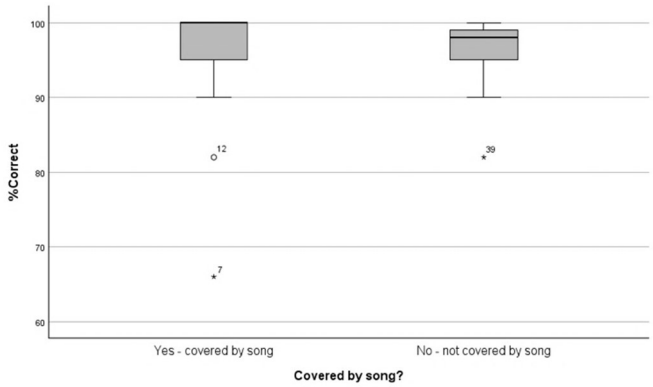


Table J.3

Tests of Normality in items covered in song vs. not covered in song subanalysis

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
%Correct	.255	50	<.001	.652	50	<.001

a. Lilliefors Significance Correction

Table J.4

Levene's Test of Equality of Error Variances[a,b] in items covered in song vs. not covered in song subanalysis

		Levene Statistic	df1	df2	Sig.
%Correct	Based on Mean	5.500	1	48	.023
	Based on Median	1.125	1	48	.294
	Based on Median and with adjusted df	1.125	1	26.861	.298
	Based on trimmed mean	2.857	1	48	.097

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Dependent variable: %Correct

b. Design: Intercept + Coveredbysong

Figure J.3

Boxplot to assess for outliers in items covered by song with familiar vs. novel melodies

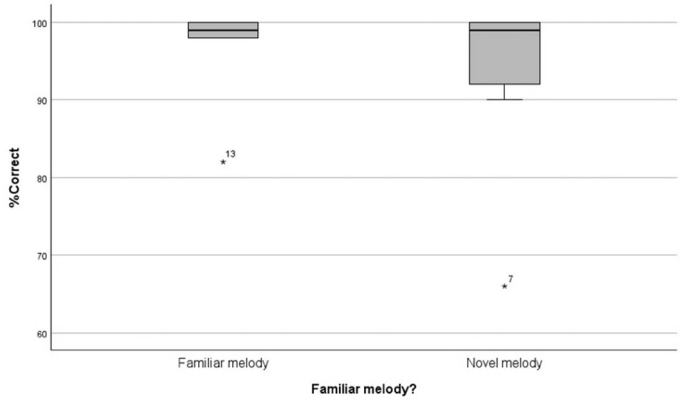


Table J.5

Tests of Normality in items covered in songs with familiar vs. novel melodies subanalysis

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
%Correct	.362	20	<.001	.592	20	<.001

a. Lilliefors Significance Correction

Table J.6

Levene's Test of Equality of Error Variances[a,b] in items covered in songs with familiar vs. novel melodies subanalysis

		Levene Statistic	df1	df2	Sig.
%Correct	Based on Mean	.128	1	18	.725
	Based on Median	.070	1	18	.794
	Based on Median and with adjusted df	.070	1	17.193	.794
	Based on trimmed mean	.073	1	18	.790

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Dependent variable: %Correct

b. Design: Intercept + Familiar melody

Figure J.4

Boxplot to assess for outliers in exam scores of students with and without musical ability

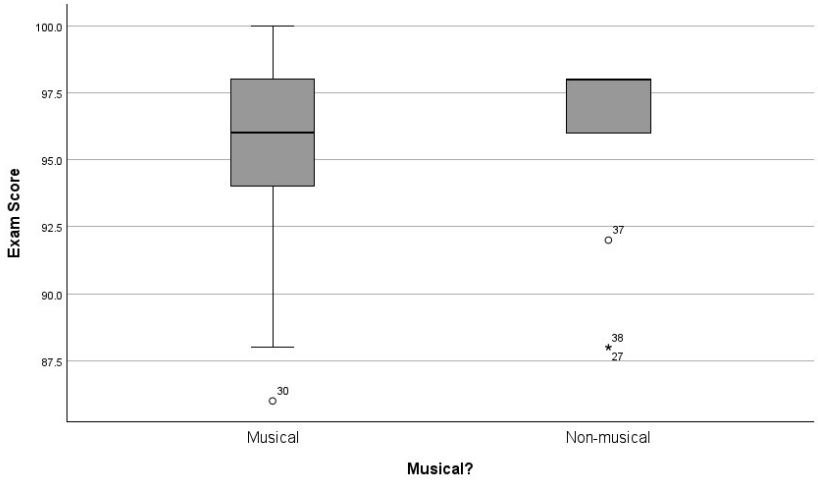


Table J.7

Tests of Normality in Exam Scores of Musical vs. Non-musical 2025 Cohort students

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Exam Score	.274	38	<.001	.810	38	<.001

a. Lilliefors Significance Correction

Table J.8

Levene's Test of Equality of Error Variances[a,b] in Exam Scores of Musical vs. Non-musical 2025 Cohort students

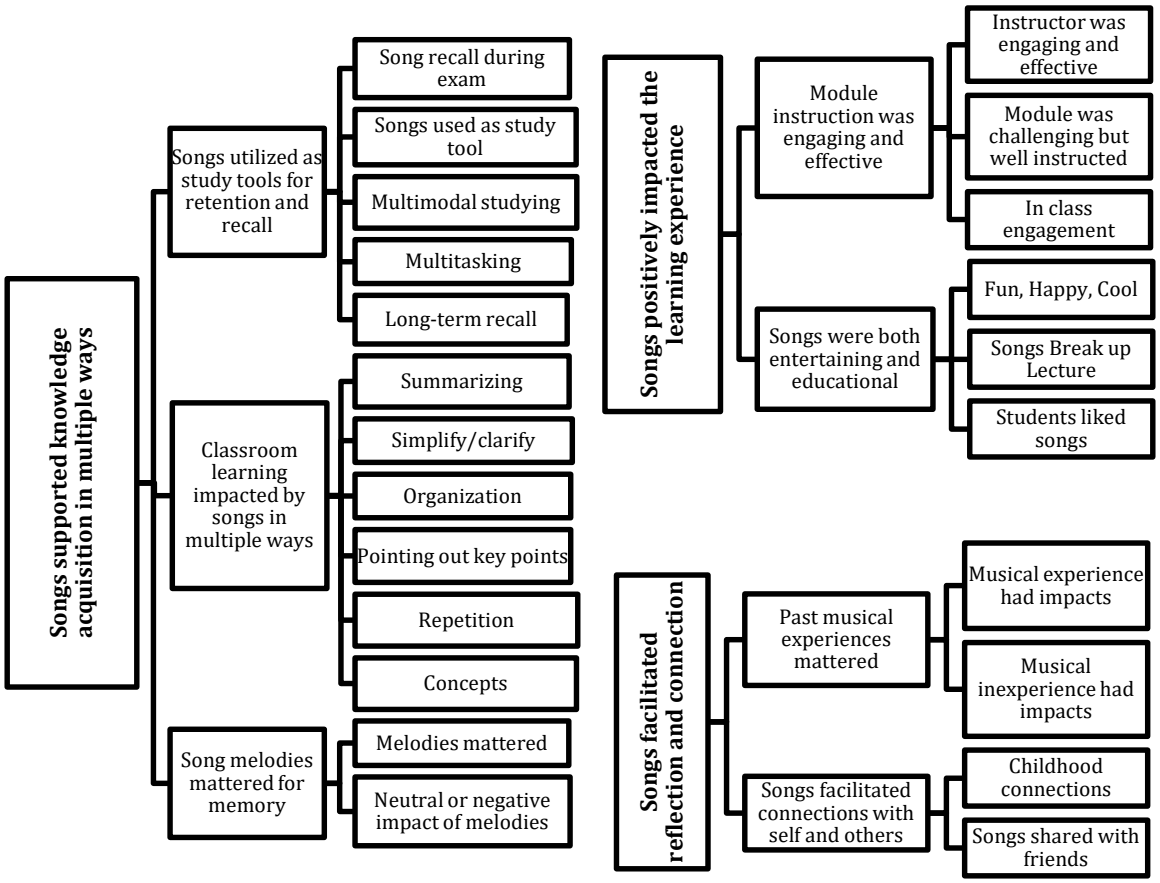
		Levene Statistic	df1	df2	Sig.
Exam Score	Based on Mean	.134	1	36	.717
	Based on Median	.284	1	36	.597
	Based on Median and with adjusted df	.284	1	33.312	.597
	Based on trimmed mean	.141	1	36	.710

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Dependent variable: Exam Score

b. Design: Intercept + Musical

APPENDIX K: Axial Codes



Note: Key to diagram. ***Themes*** *(3); Sub-themes (7); Axial codes (23)*

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