A "Puzzling Physiology and Nobel Laureates" Game: Engaging BSN Students in Physiology & Medicine

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Abstract

This article details a 'puzzling' teaching and learning method to engage undergraduate nursing (BSN) and exercise sciences (BSES) students in physiology or medicine Nobel Prize-winning discoveries, while reviewing course material through the "Puzzling Physiology and Nobel Laureates" (PPNL) game. The qualitative evaluations of 117 undergraduate BSN and BSES students revealed that 95% and 96%, respectively, agreed the game provided an opportunity to utilize critical thinking and problem-solving skillsets. Moreover, 96% of the 117 anonymous student respondents voted on increasing the number of PPNL game sessions per semester, and 94% agreeing the gamified learning strategy should be offered in subsequent classes as well. Interestingly, nearly 90% agreed that the learning experience was 'fun', and that it increased awareness of physiology and/or medicine discoveries. The style of the "Puzzling Physiology and Nobel Laureates" game lends to its reproducibility in a wide array of physiology courses for both majors and nonmajors. https://doi.org/10.21692/haps.2024.006

Key words: game; health professions students; undergraduate nursing; human physiology

Introduction

An Undergraduate Human Physiology for Health Sciences Course

A Loyola University Chicago School of Nursing health professions course in human physiology is offered to both the BSN (Bachelor of Science in Nursing) and the BSES (Bachelor of Science in Exercise Sciences) students during the spring. Prerequisite courses for enrollees are chemistry and anatomy, offered in the preceding fall semester. The demographics for the Spring 2023 semester courses taught by the author correspond with those from the previous semester enrollments between 2018 and 2022 (n = 148), and are as follows: 126 female students, 22 male students (n = 22), 117 BSN majors, 27 BSES majors, and 4 students from other majors. Since 2017, this 3-credit hour course has offered a 1-credit hour corequisite face-to-face 2D virtual laboratory (Mahaffey, 2018), in-lecture medical case studies, online exams, augmented reality learning tools, interactive peer games, memory tools such as mnemonics (Mahaffey, 2019; Mahaffey, 2021; Mahaffey, 2022). It also employs teaching and learning approaches geared toward BSN and BSES students (Mahaffey, 2023). The significant role of human physiology in BSN curricula is exhibited in the Nursing Licensure Exam Test Plan (NCLEX), as outlined by the National Council of State Boards of Nursing NCLEX Test Plan (April 2019 – March 2023) (National Council of State Boards of Nursing, 2019). Comparably, BSES majors seeking to complete licensure through the American College of Sports Medicine (ACSM) (such as the ACSM Certified Exercise Physiologist (ACSM-EP) and Clinical Exercise Physiologist (CEP) exams) complete prerequisite studies in both anatomy and human physiology (Committee on Certification and Registry Boards [CCRB], 2022). Given the hefty curricula of both programs, discussions on cognitive overload prevention and improving student engagement began to emerge.

Tackling Cognitive Overload in Undergraduate Science Courses Using Student Engagement Projects

The Cognitive Load Theory formalized in a 1956 *Psychological Review* article, by George A. Miller (Miller, 1956) was the foundation of what has been coined "Miller's Law". This concept is loosely hypothesized as the ability of individuals to retain 7 ± 2 items in a period that would later qualify as "short-term" memory. Miller's Law did elucidate two important factors: information processing and retention. Furthermore, it became the precursor to numerous hypotheses and commentaries on informational load in teaching and learning practices, as well as considerations in curriculum design. Hypotheses of cognitive load in teaching and learning have been explored in courses such as mathematics (Beserra et al., 2014), medical education (Bailey et al., 2021), biostatistics (Guzman et al., 2019), pharmacology (Kaylor, 2014), and simulated learning (Sevcenko et al., 2021). Considering cognitive load in health professions education, BSN programs generally require 120 – 130 credit hours, including science courses such as psychology, statistics, anatomy, chemistry, physiology, pathophysiology, microbiology,

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nutrition, and pharmacology (Jensen et al., 2018), coupled with clinical simulation and practice (Nursing License Map with edX, 2022). According to the Princeton Review's "What to Expect in Medical School", beyond the four years of pre-med bachelor's degree prerequisite, there are four years of medical school preceding the three to seven years of residency (The Princeton Review, 2022). The volume of knowledge one is to acquire in the health professions curricula spans a broad array of content learned in theory and practice. Additionally, success with licensure exams for BSN, BSES, and MD candidates is contingent upon innumerable study hours and reviews of test plans (Committee on Certification and Registry Boards, [CCRB], 2022; Federation of State Medical Boards [FSMB], National Board of Medical Examiners [NBME], 2023; National Council of State Boards of Nursing, 2019). Interestingly, this examination of cognitive load is not relegated to student learning but can also be observed in instructor training (Ong & Tasir, 2015), highlighting this pedagogical concern's extensiveness.

As an effort to circumvent informational overload and to increase student engagement, STEM and health sciences instructors have designed engaging and interactive learning simulations through crossword puzzles, simulated escape rooms, board games, and online anatomy-physiology games (Cardozo et al., 2016; Gómez-Urquiza et al., 2019; Hsu et al., 2023; Kane et al., 2022; Luchi et al., 2019; Taspinar et al., 2016). Educational gaming modules may help to motivate learning while abating the informational overload concerns (Huang, 2011). Today, human physiology students find interactive exercises more helpful than the sole use of an assigned text, which is why more publishers have developed supplemental e-modules to complement textbooks. A 2018 A*dvances in Physiology Education* article by Lisa Anderson highlights the aforementioned and provides qualitative survey results for 140 student participants in an undergraduate Human Physiology course ranking eight (8) resources; the top being critical thinking exercises and the fifth was a textbook (Anderson, 2018). Finding a teaching method that integrates both critical thinking exercises and textbook resources would likely improve student knowledge of human physiology course materials. Presented in this article, the author explores a puzzling method to engage BSN and BSES students as they increase allotted study group time to review textbook images and schematics while learning Nobel Prize-winning research (Anderson, 2018). This pedagogical approach creates a platform for undergraduate health professions students to improve awareness of ground-breaking research in medicine and physiology while studying textbook content.

WE NEED GAMES: The Inception of the "Puzzling Physiology and Nobel Laureates" Classroom Game

As previously noted, the structure of Marcella Niehoff School of Nursing Human Physiology for Health Professions lecture course at Loyola University includes face-to-face lectures with accompanying lecture notes and Panopto recordings accessible via a Sakai Learning Management System/ LMS course site (Apereo Foundation, 2018) that is free to enrollees, group sessions, practice assessments, trivia games, tactile physiology-pathophysiology models (Mahaffey, 2018), online games (Mahaffey, 2021), mnemonic devices (Mahaffey, 2022), augmented reality applications, and exam review sessions with complementary exam study guides (including relevant textbook topics, tables, figures, supplemental video URLs). The design of the study guide includes chapter sections topics, reference tables, videos resourced from textbook publisher and YouTube, and relative figures of pathways, anatomical depictions, and biological reactions. Since the introduction of the first course study guide in 2018 (to 2023), the author (and lecturer) noticed a study trend. This observed trend revealed student ranking of exam study guide materials as follows: Lecture Notes > Videos > Tables > Figures. The trend was identified through in-lecture student questions, emailed inquiries, and 1-on-1 meetings with enrollees. It became more apparent when the instructor would reference important figures from the exam study guide in-lecture and noticed a decline in student responses compared to references derived from lecture notes, videos, and tables. A parallel trend was established as exam questions on figure content had an observably lower response rate in comparison to the other three categories of study guide content. Whether this prioritization of review content was inadvertent or intentional remains to be evaluated. Another observation of this undergraduate health professions learning was an increase in student interest and response when the instructor would 1) introduce review materials via gamification and 2) parallel lecture content with modern-day discoveries and healthcare applications. The latter approach buoyed student awareness of scientific luminaries and their discoveries, while allowing enrollees to conceptualize human physiology outside of "classroom-thinking". Gamification is a teaching and learning approach that has been used in both STEM and nursing courses (Gómez-Urquiza et al., 2019; Taspinar et al., 2016), allowing students to review course concepts and utilize their critical thinking skillsets in an engaging platform. In the same vein, online game-based learning and information retrieval assignments have increased student interest for completing learning tasks and have aided in student retention of conceptual information (Anderson, 2018; Huang, 2011). Observations similar to these prompted the development of this "Puzzling Physiology & Nobel Laureates" game in the author's undergraduate health professions courses.

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Methods

Human Physiology Review Game: "Puzzling Physiology & Nobel Laureates"

Since 1901, the Nobel Prize has been a highly reputable and prestigious award bestowed upon researchers and members of society who have made groundbreaking and world-changing discoveries across multiple fields of research. To date, the prize includes a diploma, a gold medal engraved with the likeness of Alfred Nobel, and a monetary prize. The Nobel Prize is awarded to single, double, or triple recipients (nobelprize.org). The awardees provide a lecture and may attend a ceremonious banquet. Among the Nobel Prize award categories, are three (3) physical sciences: chemistry, physics, and physiology or medicine. Historically, there were approximately forty-nine times in which the awards ceremonies halted across all categories and these times occurred mostly during World War I (1914-1918) and World War II (1939-1945). The years in which the Nobel Prize ceremonies for physiology and medicine were suspended fall within the period of these world wars, as outlined at nobelprize.org: the years 1915, 1916, 1917, 1918, 1921, 1925, 1940, 1941, 1942. For the purposes of the "Puzzling Physiology & Nobel Laureates" game discussed, the focus of these methods will review Nobel laureate discoveries in physiology or medicine.

During this past spring semester, three rounds of "Puzzling Physiology & Nobel Laureates" game were played. Players require a laptop or iPad/tablet, access to the course textbook, and Wi-Fi. For each round, enrollees would apply depicted knowledge from textbook (and external) figures to solve for the correct Nobel Laureate name and their discovery. The selected topics corresponded with course learning outcomes, which further correlated with the American Physiological Society Core Concepts of Physiology Education (Table 1). Additionally, the Nobel Prize-winning discoveries aligned with physiology topics in upcoming exam chapters needing review from the instructor's perspective. For this semester, those focal chapters were glycolysis (more specifically Krebs cycle review), muscle physiology, and gastrointestinal (GI) system physiology (Figure 3, Q3). The resulting interactive learning goal was to promote student review of lecture and figure content within an engaged learning platform while increasing awareness of ground-breaking human physiology discoveries in medicine. The "Puzzling Physiology & Nobel Laureates" (PPNL)Mgame steps were as follows (Figure 1 for STEPS 1-5):

1. PUZZLES: Student participants were provided with an in-lecture PowerPoint slide presentation depicting several figures to decode the last name of the respective Nobel Laureate.

a. Given the likelihood of occurrence for common surnames, categories were provided to focus player searches in STEP 2. To elaborate, for the 1953 physiology or medicine prize awarded to H.A. Krebs for his discovery of the citric acid cycle in carbohydrates, the category was *"A Biochemical Process for ATP production*" (Figure 2). Another example is the 2005 prize in physiology and medicine to Robin Warren for his shared "discovery of the bacterium *Helicobacter pylori* and its role in gastritis and peptic ulcer disease" (Nobelprize.org), in which the PPNL segment was categorized as *"Tummy Ache"* and accompanied with an image of a pained stomach.

b. The PowerPoint slide contained a series of four image/figure depictions from the textbook (Stanfield, 2017) and external sources. Two images per row, with two rows of images on the slide. Participants review clues from left to right for each row in lecture with the option to take a photo for review outside of class (Figure 2).

c. Above each depiction was a clue. For example, "The FIRST two letters of the metabolic pathway depicted here." or "The FIFTH LETTER of the main product from the hypothalamus in the feedback pathway depicted below."

d. The resulting clues, with the prerequisite review of figures, revealed a LAST NAME.

2. DISCOVERIES: Following step 1, each participant would visit Nobelprize.org website, to search for the Physiology or Medicine Nobel Laureate of interest by last name that completed research in the highlighted category.

3. STUDENT GROUPS DISCUSSION: Students were permitted to work in groups of 2-4 to discuss figures as they attempted to solve each puzzle, initially during lecture with peers. Additional time was allotted for review outside of lecture with peers.

4. SOLUTION: Once the student has identified the likely Nobel laureate, they would log into Sakai LMS ("Tests & Quizzes" tab), and complete the 3-question Puzzle Solver Quiz (and submit). Although this was an optional exercise, additional participation points were provided to participants.

a. Name of Laureate

b. Year of Discovery

c. Description of Nobel Prize-winning discovery

5. IN-LECTURE REVIEW: Following submissions, a lecture presentation that includes a class discussion is used to draw connections between the highlighted Nobel Prize research, human physiology lecture content, and healthcare.

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Select Human Physiology for Health Professions Didactic/Laboratory Course Outcomes	The Core Concepts of Physiology[a] (based on Michael- McFarland 2011 Rankings)	Puzzling Physiology & Nobel Laureates (PPNL) Game: Selected Nobel Laureates (Year of Award)[b]
Upon completion of this course the student will be able to… **Describe the normal physiology of cells and tissues in the human body.**	*Cell membrane, Homeostasis, Cell-Cell communications, Interdependence, Flow down gradients, Energy, Structure/ Function, Physics/Chemistry, Genes to proteins, and Levels of organization.*	**A.V. Hill (1922)** *"for his discovery relating to the production of heat in the muscle"*
		H.A. Krebs (1953) *"for his discovery of the citric acid cycle"*
Examine the physiological interaction between organs and systems in the human body.	*Homeostasis, Cell-cell communications, Interdependence, Scientific Reasoning, Physics/Chemistry, Levels of Organization, and Mass balance.*	**A.V. Hill (1922)** *"for his discovery relating to the production of heat in the muscle"*
		H.A. Krebs (1953) *"for his discovery of the citric acid cycle"*
		J. R. Warren/B.J. Marshall (2005) *"for their discovery of the bacterium Helicobacter pylori and its role in gastritis and peptic ulcer disease"*
Explain the role of body systems and physiologic mechanisms in maintaining homeostasis.	*Cell membrane, Homeostasis, Cell-Cell communications, Interdependence, Flow down gradients, Energy, Structure/ Function, Scientific reasoning, Cell theory, Physics/Chemistry, Genes to proteins, Levels of organization, Mass balance, and Causality.*	**A.V. Hill (1922)** *"for his discovery relating to the production of heat in the muscle"*
		H.A. Krebs (1953) *"for his discovery of the citric acid cycle"*

[a] Core Concepts were adapted from those outlined by the American Physiological Society Center for Physiology Education, and as described by Michael and McFarland (Michael & McFarland, 2011) .
[b] Nobelprize.org

Table 1. *Comparison of Course Outcomes, APS CPE Core Concepts and PPNL Game Nobel Laureate Discoveries*

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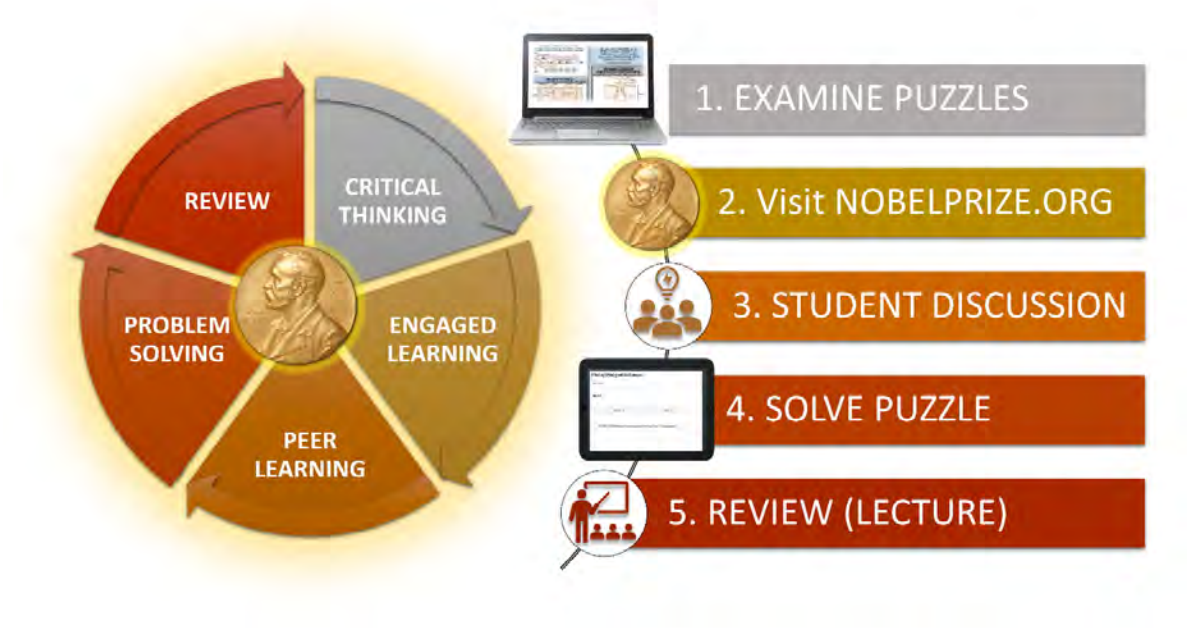

Figure 1. *Process and learning approaches for the "Puzzling Physiology & Nobel Laureates" Game.*

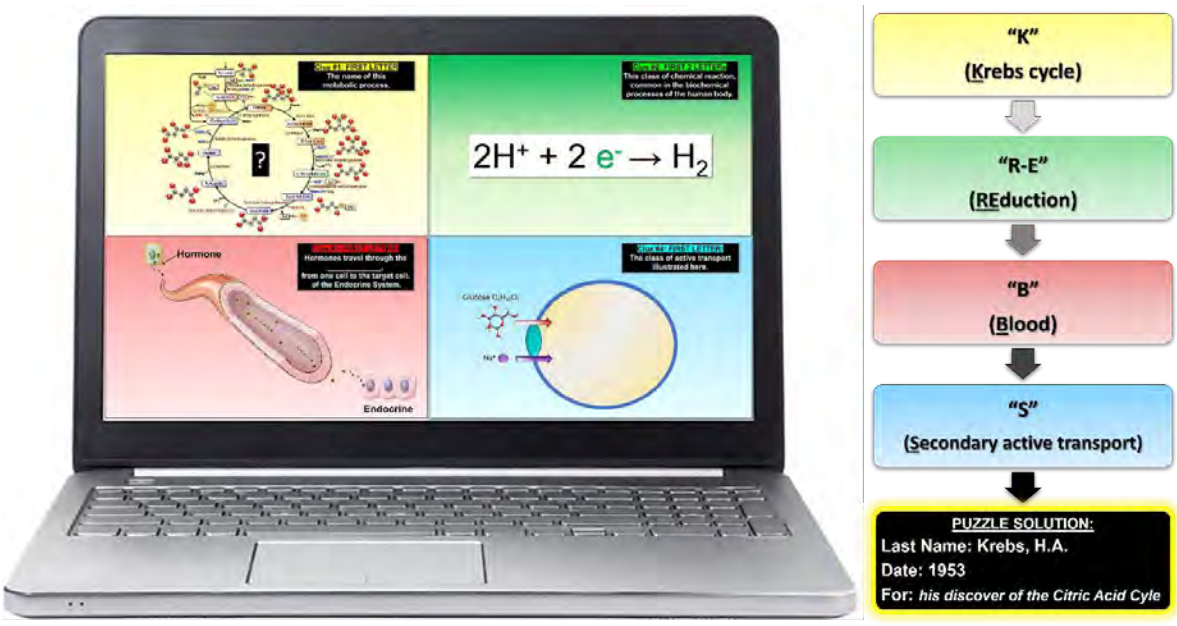

Figure 2. *A depiction of one of several "Puzzling Physiology & Nobel Laureates" Games (left) and the solution (right). This PPNL game segment includes clues for the 1953 Physiology or Medicine Nobel prize-winning discovery of the citric acid cycle by H.A. Krebs. Images were both created by the author and sourced from Wikimedia.*

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Development of a Qualitative Survey: An anonymous Qualtrics XM survey was formatted with security settings for one submission per person. The URL for the anonymous survey was shared in a group chatting app for the Spring 2023 Human Physiology for Health Professions course. A call for volunteers (including the link) was shared to the same app. Student anonymity was guaranteed via Qualtrics XM settings. Of the 148 enrollees in the Spring 2023 semester course, 117 opted to complete the Qualtrics XM online survey. The survey was a voluntary qualitative review of the "Puzzling Physiology and Nobel Laureates" game. Data from the survey was exported and analyzed. The anonymous survey results for the 117 student participants are discussed in the results section of this article. The results of the Qualtrics XM survey were divided into two parts: Part A) a review of BSES/BSN student responses to the selected Noble laureates and corresponding discoveries and Part B) a review of BSES/BSN student responses concerning the PPNL game in the undergraduate Human Physiology for Health Professions course. The Loyola University Chicago Health Sciences Division Institutional Review Board has exempted the qualitative analysis and data gathering of this physiology course's teaching and learning games and additional innovative approaches.

Results

Qualitative Survey: "Puzzling Physiology & Nobel Laureates" Game and Student Learning

Qualitative Survey PART A (Figure 3): Part A is a three-question series reviewing the PPNL game design. For this portion, 117 PPNL game participant responses were recorded. The first question assessed student-perceived difficulty in the PPNL game instructions, respondents were asked to select one of the five-point Likert-modelled measures: ranked from "Extremely Easy" to "Extremely Difficult" (Figure 3, Q1). More than 64% found the PPNL instructions as easy to follow with 19% as "Neither Easy/Difficult". As the PPNL five-step game instructions were presented during lecture, on a single PowerPoint slide, the survey results suggest that an improvement in the delivery of PPNL game instructions in future semesters may be helpful. The author theorizes that a single PowerPoint slide of game instructions may best serve participants if either provided in Sakai (versus in lecture) for each participant to review at their own pace; or dividing instructions into multiple PowerPoint slides (allowing for a one-step per slide presentation of instructions). The second question inquired about the three PPNL game categories used in this Spring semester: Cellular Metabolism (Krebs cycle), Muscular System, and Gastric System (Figure 3, Q2). Of the 117 participants, 52% selected all categories as most interested, having a disbursement of single responses for Krebs Cycle and Gastric System, with Muscular System edging out both choices. Lastly, for the Most Interesting Discovery, 115 participants responded with a wide range of selections (Figure 3, Q3). Here, the most interesting discovery was that of J. Robin Warren (2005), for his discovery of the role of H. *pylori* bacteria in peptic ulcers. This is intriguing as the "Gastric system" PPNL Game category was the least interesting (Figure 3, Q2). Students offered no explanation in the free response section of the survey to explain this curiosity. The qualitative results of both questions two and three (Figure 3, Q2 – Q3) display varied interests in the Nobel Prize-winning discoveries emphasized in this undergraduate health professions physiology game. On the success of the PPNL game, questions two and three reflect a catalyzation of student interest in physiology and medicine discoveries, which was an important goal in the PPNL game design.

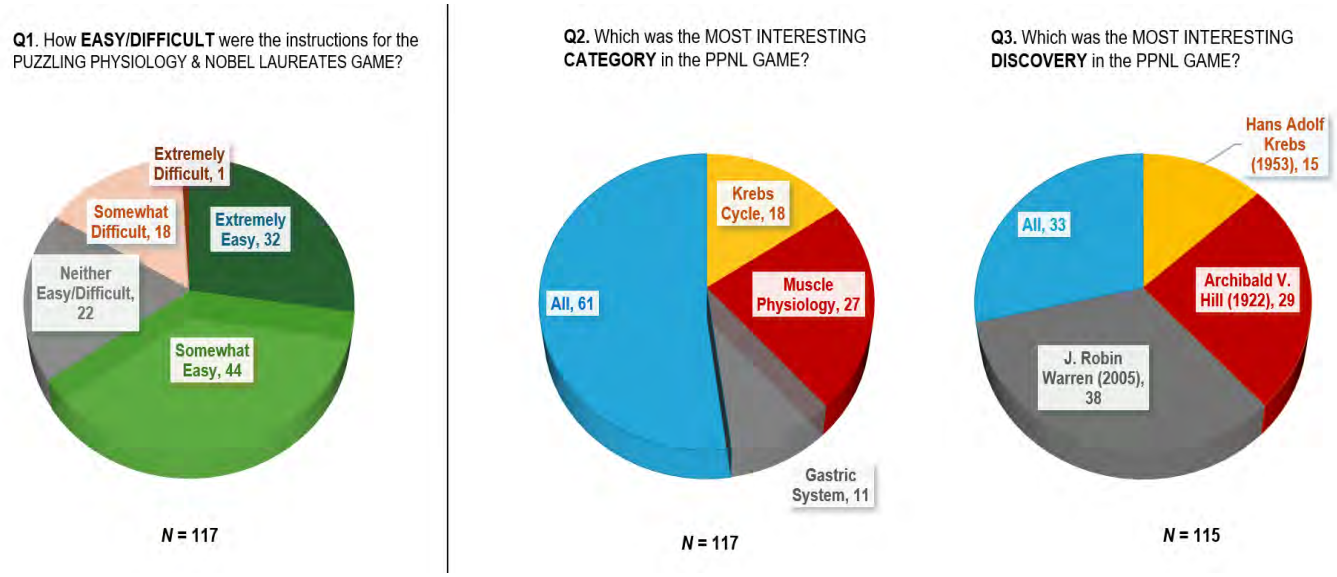

Figure 3. *Qualitative (PART A) student responses to the "Puzzling Physiology & Nobel Laureates" (PPNL) Game in an Undergraduate Health Professions Course.*

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Qualitative Survey PART B (Figure 4): Part B of this anonymous PPNL game survey reviews the remaining six questions (Figure 4, Q4 – Q9), which discuss student recommendations and evaluation of the PPNL game and design. The five-point Likert scale for PART B evaluation ranged from "Strongly Agree" to "Strongly Disagree". Of the 117 respondents 96% would find it helpful if the PPNL game was available throughout the semester of human physiology (more than three times per semester) (Figure 4, Q4). Regarding the PPNL game being a "helpful" tool in reviewing relative chapter concepts and Nobel Prize-winning discoveries in Physiology and Medicine (Figure 4, Q5), 88% of the 117 participants agreed. Here, another goal of the PPNL game design was actualized, as student interest in medicine and physiology was a tenet of this gamified learning approach. In measuring student engagement, a question (Figure 4, Q6) on whether the PPNL was a "fun" exercise again showed that 88% agreed. Regarding students utilizing problem-solving and critical thinking skills, 95% and 96% respectively of participants agreed the PPNL game promoted the use of these skillsets (Figure 4, Q7 – Q8). On another positive note, of the 117 respondents 94% advocated for the continued offering of this PPNL game in the following semester human physiology for health professions courses (Figure 4, Q9).

A Comment on Cognitive Overload Mitigation and the PPNL GAME

Several indicators of cognitive overload include feelings of anxiety or stress in learning, being overwhelmed, difficulty applying critical thinking, problem-solving skills, and deductive reasoning during inquiry-based learning (Cezar, 2023). The qualitative data for the PPNL indicate, among other things, that the game was fun, allowed students to utilize critical thinking and problem solving with ease, and students would recommend continued implementation of the PPNL game in succeeding courses. There were no indicators from the data nor student comments for anxiety, a sense of being overwhelmed, difficulties focusing on problem-solving not stress in learning topics. The absence of cognitive overload indicators and positive student responses were indicative of overload mitigation and promotion of a positively effective learning exercise.

Figure 4. *Qualitative (PART B) student responses to the "Puzzling Physiology & Nobel Laureates" (PPNL) Game in an Undergraduate Health Professions Course.*

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Qualitative Survey on Nobel Prize Ceremonies and Physiology and Medicine

The author was interested in student awareness of the Nobel Prize ceremonies and more specifically their knowledge of physiology and medicine prize winners, preceding the PPNL game, so another qualitative survey was offered to participants via Qualtrics XM (Figure 5). Given that this anonymous and voluntary survey offering was during the final examinations period, 97 responses for this three-part and three to five-point Likert-type survey were collected. Q1 of the survey inquired if participants had an underlying awareness of the Nobel Prize prior to the PPNL game, in which 55% of respondents gave a reported "yes". As a note, the result may underscore an opportunity for more Nobel Prize-winning discoveries to be discussed in high school or undergraduate STEM and health textbooks because most respondents are first-year undergraduate students. The second survey question asked whether respondents were aware of the Nobel Prize specifically offered for physiology and medicine discoveries before participating in the Spring semester game. Only 21% of these respondents voted in the affirmative (Figure 5). Once more, the author stresses the need for incorporating more Nobel Prize-winning discoveries in STEM (and health) textbook materials, especially for future health professionals and physical scientists - as these discoveries are often the foundation of STEM and health sciences education. Lastly (Figure 5, Q3), when asked of their likelihood of watching the upcoming Nobel Prize announcements after completing the PPNL game, students responded using a five-point Likert-modelled scale of "Very Likely" to "Not at All" and nearly 82% indicated a likelihood to stay apprised of the Nobel Prize in Physiology and Medicine announcement of winners. The results underline the efforts of the PPNL game to buoy student awareness of up-to-date physiology or medicine discoveries and interest in the Nobel Prize awards.

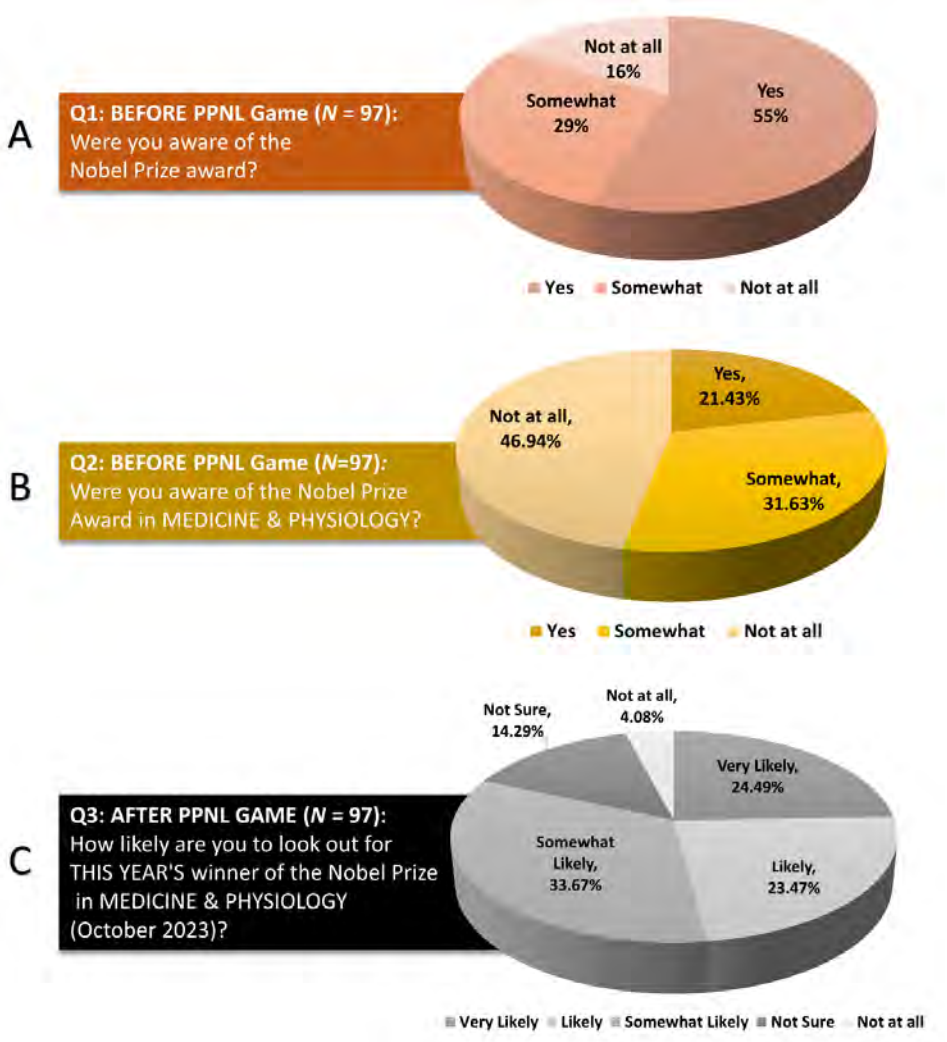

Figure 5. *Post "Puzzling Physiology & Nobel Laureates" Game qualitative student participant survey results on the Nobel Prize ceremonies.*

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Conclusion

The aim of the PPNL game was to offer a series of engaging assignments for BSES and BSN students enrolled in an undergraduate Spring semester human physiology course for health professions. The platform gamified the textbook figures in an effort to promote student review of course materials and enhanced awareness of Nobel Prize-winning discoveries in physiology or medicine. Post-game qualitative research highlights the engagement and critical thinking aspects of this online game assessment. Given the results discussed, a plan is to incorporate more Nobel Prize discoveries into a larger scale "Puzzling Physiology and Nobel Laureates" game (i.e., offering more than three categories of matching course topics with physiology and medicine discoveries) for succeeding courses of human physiology for health professions.

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Author Contributions

A.L.M. conceived and designed research; performed experiments; analyzed data; interpreted results of experiments; prepared table; drafted manuscript; edited and revised manuscript; and approved final version of manuscript.

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