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Analyzing the Correlation Between Students' Knowledge of Newton's Laws of Physics and Their Enjoyment of Watching Marvel Films

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ABSTRACT

The Marvel Cinematic Universe (MCU) has produced numerous worldwide box office hits such as *Avengers: End Game*, *Avengers: Infinity Wars*, and the *Spiderma*n series. However, previous researchers discovered countless numbers of the feasibility of the physics within these films. The ongoing discussion among the scientific community led to the aim of my research: to examine if there exists a positive or negative correlation between a viewer's knowledge of science, particularly Newton's Laws, and their enjoyment of Marvel films, specifically superhero movies. To determine the relationship between students' scientific literacy and their enjoyment of watching Marvel films, I conducted two types of quantitative research: a pre-validated Half Force Concept Inventory test and a Two-Sample Independent t-Test conducted on 91 students in four AP Physics 1 classes in X High School. My study concluded that the correlation between the viewer's knowledge of science, particularly Newton's Laws, had no significant relationship with their enjoyment of watching Marvel films.

INTRODUCTION

Background

As one of the highest-grossing film franchises worldwide, the Marvel Cinematic Universe (MCU) holds numerous record-breaking films and has received a variety of nominations and awards for its cinematography and visual effects. With a "total worldwide box office revenue of 22.93 billion, the MCU tops many other widely praised film franchises and series such as *Star Wars* (10.32 billion) and *Harry Potter* (10.32 billion)" (Statista 2021).

Highest grossing film franchises and series worldwide as of August 2021 (in billion U.S. dollars)
Highest grossing film franchises and series 2021

	Total worldwide box office revenue	Average revenue of series	Highest grossing film in series
Marvel Cinematic Universe	22.93	0.96	2.8
Star Wars	10.32	0.86	2.06
Harry Potter	9.22	0.84	1.33
Avengers	7.75	1.94	2.8
Spider-Man	7.22	0.72	1.13
James Bond	7.12	0.26	1.11
Fast and the Furious	6.59	0.66	1.52
X-Men	6.08	0.47	0.79
Batman	6.04	0.43	1.08
Peter Jackson's Lord of the Rings	5.85	0.84	1.12
DC Extended Universe	5.78	0.58	1.14
Jurassic Park	5.01	1	1.67
Transformers	4.85	0.69	1.12
Pirates of the Caribbean	4.52	0.9	1.07

Figure 1. Highest grossing film franchises and series worldwide as of August 2021.

Despite its acclamation, insufficient attention has been paid to the credibility of physics presented in these films. As a result, my research aims to examine the validity of the physics concepts, particularly, Newton's Laws, and how it increases scientific literacy in high school students.

Though the collected research acknowledges the accuracy of the physics within the films, current studies fail to connect how they offer a pedagogical entry point for scientific literacy for high school students. Regardless of whether students grasp theoretical scientific information, it is equally crucial that they gain applied skills and experience learning science.

Though most Marvel movies frequently violate laws of physics, specifically Newton's Laws of Motion, I hypothesize that they will exhibit a positive correlation between a student's knowledge of physics and their enjoyment of Marvel films, specifically superhero films.

Definitions of Key Terms

An understanding of the following terms is crucial to understanding this study. To begin with, the term Newton's Laws of Physics refers to the "three statements describing the physical relations between the forces acting on a body and the motion of the body" (Britannica). For the purposes of my study, I will not expound on each explanation of the laws; however, it is useful to know that these three laws are key concepts used as a testing method for my methodology.

Second, according to the author and professor Jane Maienschein, the term scientific literacy "emphasizes scientific ways of knowing and the process of thinking critically and creatively about the natural world" (1988). In other words, scientific literacy is a person's ability to describe, explain, and predict scientific concepts. This is important to address as it refers to my research question of how students' scientific literacy correlates to their enjoyment of Marvel films. This vocabulary term will also be mentioned in my literature review to emphasize the importance of scientific literacy in high school physics classrooms.

Lastly, the term critical thinking is the "process of skillfully conceptualizing, applying, and analyzing the information gathered from observation, reasoning, or communication, as a guide to belief and action" (Scriven et. al 1987). This is an important term to establish as it is heavily mentioned throughout my literature review section, which I will be addressing next.

LITERATURE REVIEW

Growth of Critical Thinking Through Marvel Films

In order to understand if there exists a positive or negative correlation between a viewer's knowledge of science, particularly Newton's Laws, and their enjoyment of Marvel movies, specifically superhero movies, it is important to examine the existing body of research on the topic. A study conducted by Efthimiou et. al, claims that these films completely disregard physics and suggest that the audience watching these Marvel films should increase awareness by using critical thinking in real life (Efthimiou et al., 2007). This study explores the inconsistency of the physics depicted in popular Marvel films and uses analytical research — a method that uses the facts that have been confirmed already to form the basis for the research and critical evaluation of the material — and conducts an analysis to determine which physics concepts each scene violates. As concluded by Efthimiou et al., "...many scenes are created with absolute disregard of the physical laws in our universe [...] sometimes, the scene is so profoundly created that it is hard to be missed" (19). Research indicates that because the films convey the lack of logic and scientific literacy of physics, it creates a significant disconnect from the movie. Even though the films portray the physics concept incorrectly, they provide opportunities for physics teachers to use as examples of why these facts are wrong. As a result, students can exercise critical thinking by discussing ways to correct the physics in the film. By posing hypothetical scenarios in which students must justify their interpretation of physics with a line of scientific reasoning, the films automatically enhance their critical thinking skills and, in turn, increase their scientific literacy. Marvel films, however, are only one example of a pedagogical tool that physics instructors can use to improve students' critical thinking; cartoons have already been proven to achieve this goal.

Growth of Scientific Literacy Through Cartoons

The relationship between cartoons and the growth of scientific literacy is further discussed by Mico Tatalovic, a science journalist in Knight Science Fellowship Journalism at Massachusetts Institute of Technology (MIT), who highlights the importance and effectiveness of utilizing superhero comics to teach science. Tatalovic expresses, "The Science of Superheroes (2002) and The Physics of Superheroes (2005) [are] two excellent books about the science behind the superpowers and how to use those in teaching students about science […] [F]iction comics often get the science 'facts' wrong but can still be used as interesting examples of why something is wrong and what science tells us about such phenomena" (3). To increase critical thinking in students, "...single frame "Concept Cartoons" which have been used to improve physics education and public interest in science…depict a single problem such as: "Would the snowman [featured in the cartoon] melt faster, slower or at the same rate if we put a coat around it?" (Tatalovic 3). Cartoons like these allow scientific discussions among students by using thoughtful reasoning (see Figure 2).

Figure 2

Gaps in the Research

Unlike the studies conducted by Efthimiou et al. and Tatalovic, research analyzing the practicality of physics presented in Marvel films does exist (Westrup, 2002; Buren, 2021). Westrup's study presented a short description of each scene where physics was present in films such as *Spiderman* and determined the feasibility of physics within the scene. He then ensured that students were able to differentiate the correct physics present in the film. In a similar vein, Buren's research suggests that, contrary to common belief, the scientific theory of the multiverse does indeed exist. To prove her hypothesis, Buren uses Max Tegmark's *Four Levels of the Multiverse* to compare and contrast the four different types: quilted, bubble, quantum, and theoretical. She presents multiple films that include a concept of the multiverse from the Marvel franchise such as *Spiderman: Into the Spiderverse (2018)* and *Avengers Endgame (2019)*. In short, both of these researchers analyze how physics within the Marvel franchise films is indeed feasible in real life. They are limited, however, since they do not take into account how these Marvel films provide a pedagogical entry point into increasing students' scientific literacy. Scientific literacy — which "emphasizes scientific ways of knowing and the process of thinking critically and creatively about the natural world" (Maienschein 1998) — is integral to learning scientific concepts, especially when analyzing physics concepts from Marvel films.

As previously mentioned, using fictional media, such as comic books or strips, can educate students about different scientific concepts and bring entertainment value to the reader. For example, "*LabRatz* is a three-frame comic strip inspired by day-to-day life in a scientific laboratory[.…] [W]hile *PhD Comics* draw their inspiration from lives of graduate students… *Newton and Copernicus* follows the adventures of two lab rats and has been successfully used in science education to raise scientific literacy of students" (Tatalovic 6; refer to Image 3).

Figure 3

However, "existing studies highlight the potential benefits of using such comics in science education, but do not address the use of comics and graphic novels as a means of communicating science to people outside classroom settings" (Tatalovic 13). These studies aim to investigate the plausibility of the physics present in the Marvel franchise films; therefore, their data solely proves the reasoning behind the inaccuracy of the physics concepts rather than the outcomes of using them in physics classrooms.

While few studies assert that the plausibility of physics concepts within Marvel films drives students and teachers to initiate growth in physics classrooms, others argue that it ruins not only the film itself but also plants inaccurate knowledge into students' learning. Moreover, given the limitations of previous studies, any research on Marvel films that are used as teaching tools in classrooms must focus on how students can experience enthusiasm while learning physics by watching such films. According to a Statista survey on the "public opinion on superhero films by age group, specifically focusing on 18-29-year-olds, 55% stated that they enjoy superhero movies and will continue to see them in theaters, 23% stated that they enjoy superhero movies, but are [repetitious], and roughly 16% stated that they do not enjoy superhero movies" (Statista; refer to Figure 4).

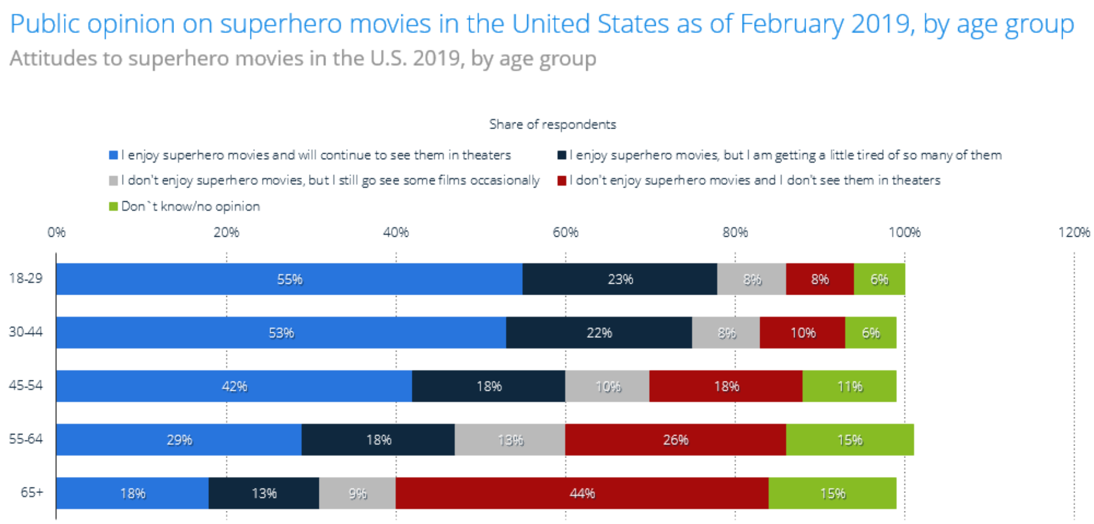

Figure 4

Hypothesis

From the data, I hypothesize that people who don't necessarily enjoy superhero movies are scientifically literate; therefore, they can successfully identify most of the scientific fallacies present within the films and, thus, lose interest in watching such films. Therefore, this paper will aim to analyze the correlation between viewers of Marvel films' scientific literacy and their enjoyment of watching superhero movies.

Educational Benefits of Marvel Films

Seeing as studies have not looked at the learning outcomes illustrates that imminent research should be centered on the educational benefits of Marvel Films. Learning physics only portrays the superficial aspects of the physics curriculum, as it does not fully develop an applied understanding of scientific literacy beneath it. Students are able to apply the scientific method, which will help them formulate scientific hypotheses and alternate solutions. The use or misuse of basic physics principles can serve as an entry point to a discussion about the basic laws of physics.

Additionally, there needs to be a curriculum that appeals to divergent forms of student learners. Students have diverse learning styles — some are hands-on learners, who learn with physical activities — some are visual learners, who learn with visual aids such as pictures, videos, graphs, and maps. Teaching physics isn't just about helping students memorize equations, but rather, a way to resonate with different learning styles, which ultimately serves to enhance scientific literacy. My study will be unique as it will attempt to bridge the previously mentioned gaps in research by investigating whether there exists a positive or negative correlation between a viewer's knowledge of science, particularly Newton's Laws, and their enjoyment of Marvel movies, specifically superhero movies.

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METHODOLOGY

Overview

The goal of this research is to determine the relationship, if any, between a high school student's knowledge of Newtonian mechanics and their enjoyment of superhero movies in the Marvel franchise. The widespread popularity of Marvel films offers physics educators unique access to a population whose interest in these movies provides an entry point to identify, connect to, and refine students' understanding of Newtonian mechanics. To test the claim that there is a correlation between a student's scientific literacy and their enjoyment of Marvel films, a quantitative research method using a Half Force Concept Inventory test and a Two-Sample t-Test was applied. Quantitative studies are statistical, mathematical, or numerical analyses of data collected through polls and surveys (Babbie et. al 2010). The use of a quantitative study worked effectively because analyzing my data using the Two-Sample t-Test requires statistical data (ex. test scores) to calculate the t and p-values, which will be discussed later in the results section.

Half Force Concept Inventory Test

To carry out this research, first, I administered a Half Force Concept Inventory test (HFCI), which tests students' understanding of common Newtonian physics concepts such as velocity, acceleration, and force. This test was effective as "it is widely held as the 'gold standard' conceptual inventory in the Physical Sciences" (Wells et. al). I chose to use this assessment, as it will test a student's baseline understanding of force concepts, which will be used as part of my data to analyze a high school student's knowledge of physics concepts to their enjoyment levels in Marvel films. The questions are roughly half the size of the original Force Concept Inventory test (FCI), containing only 14 questions, instead of 30 questions. The HFCI format allows students to complete testing in a shorter amount of time, taking only 15 minutes to complete rather than the FCI's 30-minute exam. Figure 5 displays a question from the HFCI test below to give an example of how the test is formatted.

A stone dropped from the roof of a single story building to the surface of the earth:

(A) reaches a maximum speed quite soon after release and then falls at a constant speed thereafter.

(B) speeds up as it falls because the gravitational attraction gets considerably stronger as the stone gets closer to the earth.

(C) speeds up because of an almost constant force of gravity acting upon it.

(D) falls because of the natural tendency of all objects to rest on the surface of the earth.

(E) falls because of the combined effects of the force of gravity pushing it downward and the force of the air pushing it downward.

Figure 5

Population Sample

The subjects of this study were students who are currently enrolled in an AP Physics 1 class. Grade level and gender were exempt from participant selection. This sample was chosen specifically because these students have most recently completed learning about the kinematics unit, which is required to take the HFCI test.

Procedure

An excel spreadsheet containing all of the teacher's schedules was provided, and I was able to determine that I could distribute the HFCI tests to four of the AP Physics 1 classes. All four classes were given the same assessment; however, only paper copies were provided in order to give the students a chance to use the paper for sketches or calculations to help with their tests. Instead of having proctors, I went into each class and proctored the class myself. This approach reduces the chances of errors that other proctors (that isn't me) could make, such as skipping steps or not abiding by the time guideline. As the Physport assessment guidelines suggested, 15 minutes was enough time for a student to complete the test. A consent form was attached in front of the HFCI test to assure that the student's participation was optional and anonymous and by signing their initials at the bottom of the page, their data would be included in the study.

Data Analysis

Upon completion of the HFCI tests in all four AP Physics 1 classes, I gathered the tests and graded them individually using a 14-point scale. A student with the highest score possible would receive a 14/14 — which can be interpreted as a student who has high scientific literacy, or in other words, more than sufficient knowledge of science, specifically Newton's Laws. Vice versa, a student with the lowest score possible would receive a 0/14 — which can be interpreted as a student who has low scientific literacy, meaning they have insufficient knowledge of Newton's Laws concept.

The scores were organized in an Excel spreadsheet, and each column was labeled Test Scores and Marvel Film Enjoyment Level. In the column labeled Test Scores, each individual's test scores (the number of questions they got correct) were entered into the chart. On the other hand, in the column labeled Marvel Film Enjoyment, the yes or no responses were reinterpreted into Yes=1 and No=0, to quantify the nominal data. The data was then normalized by finding the mean, median, and standard deviation of each column (Test scores of people who enjoy watching Marvel films versus the Test scores of people who do not enjoy watching Marvel films). This ensures the accuracy and validity of my data prior to analysis. The HFCI scores with their matching enjoyment levels were then categorized into two groups: people who enjoy watching Marvel films and those who do not enjoy watching Marvel films. Recategorizing these data sets renders the process of conducting the Two-Sample t-Test more effective as there are now two groups to analyze.

Subsequently, by determining the mean, median, and standard deviation of my data, I was able to figure out the normal distribution of my data.

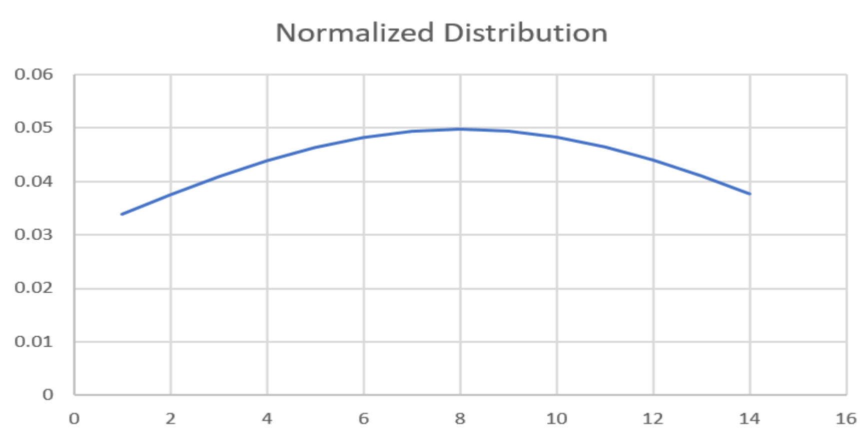

Figure 6

The graph of the normalized distribution of my data is presented in Figure 6. A bell curve is a good representation that the test was reliable. Since my HFCI test was a pre-validated test from Physport, it guarantees a normalized distribution of my data even without the bell curve graph.

Two-Sample Independent t-Test

Afterward, I administered a Two-Sample Independent t-Test to analyze if there exists a positive or negative correlation between students' scientific literacy and their enjoyment of Marvel films. A Two-Sample t-Test (also known as the independent samples t-Test) is a method used to test whether two groups of the unknown population are equal or not (JMP). To carry out my t-Test, I used the Excel data analysis feature to conduct a t-Test of Two-Sample Assuming Unequal Variances. Since this is an independent 2 Sample t-Test, we must assume that the variance between the two groups is equal. After inputting my HFCI scores into the Excel data analysis tool, the system would provide the output of the t-value, p-value, and the critical values, ultimately determining whether or not my hypothesis is true.

INITIAL ASSUMPTIONS

Prior to the discussion of my results, my initial assumption for my data was that a correlation exists between students' test scores and their enjoyment of watching Marvel films. Students with a high HFCI score are presumed scientifically literate - developing less enjoyment in watching Marvel films as they are able to point out the scientific fallacies within the film better. Students with a low HFCI score are presumed scientifically illiterate — developing more enjoyment in watching Marvel films as most of them fail to address the feasibility of physics within the film. In addition, I expect an equal or similar proportion of students who enjoy or do not enjoy watching Marvel films.

RESULTS

Box and Whiskers Plot

In total, 99 people from four different classes of AP Physics 1 completed the HFCI test. However, scores of eight people from the four classes were excluded in the study as they have either opted out or unfinished the test. In short, only 91 responses were validated for my study. Out of the 91 responses, 79 people stated that they enjoy watching Marvel films and 12 stated that they do not enjoy watching Marvel films. Before examining the results for my Two-Sample t-Test, we can begin by assessing the box and whisker plot data for the HFCI test scores between the two groups.

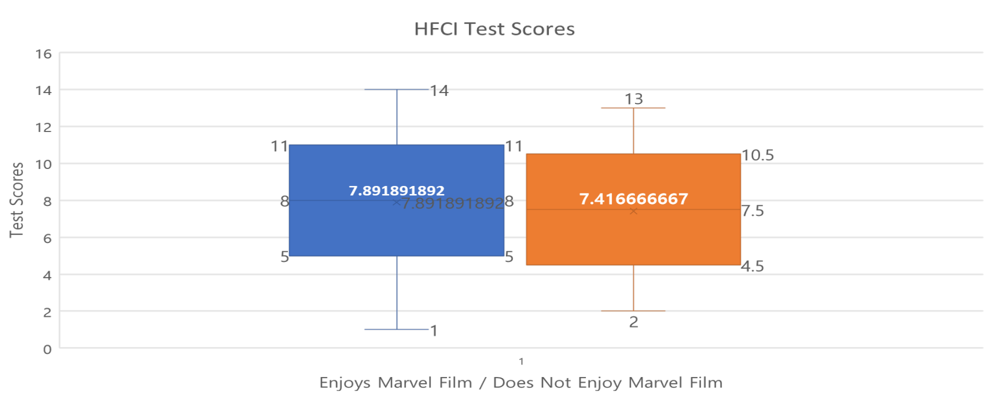

Figure 7

As previously mentioned, the above graph (See Figure 7) represents the box and whiskers plot for the HFCI tests scores between the people who enjoy watching Marvel films, represented as the blue box on the left, and the people who do not enjoy watching Marvel films, represented as the orange box on the right.

The top and bottom two values, which are shown as a 1 and a 14 for the blue box, and 2 and a 14 for the orange box respectively, represent the maximum and minimum values of my data. It exhibits the lowest and highest scores a student received in each group. The maximum score a student could receive on the HFCI test was out of 14, and we can see that a student from the group of people who enjoy watching Marvel films received a perfect score, unlike the people who do not enjoy watching Marvel films.

The middle of my data, displayed in a white bold font, represents the median, or the average test scores of the two groups. The people who enjoyed watching Marvel films received an average score of 7.89 while the people who did not enjoy watching Marvel films received 7.42. I was able to conclude that the average scores for the two groups are very similar; however, the students who did enjoy watching Marvel films had a slightly higher average than the students who did not enjoy watching Marvel films.

From the box and whiskers plot data, we are able to observe that the blue box plot (representing the people who enjoy watching Marvel films) is skewed marginally higher than the orange box plot (representing the people who do not enjoy watching Marvel films). The graph reveals that there are slightly more students who scored higher on the HFCI test than those who enjoy watching Marvel films than those who do not enjoy watching Marvel films. With the box and whiskers plot alone, it can be inferred that the correlation between scientific literacy among students and their enjoyment of Marvel films was to some degree significant.

Two-Sample Independent t-Test Data

Moving on to my Two-Sample Independent t-Test data, the main purpose of this test was to analyze whether there was significance between the student's knowledge of scientific literacy and their enjoyment of Marvel films. The following table (refer to Figure 8) represents the table for my t-Test values.

	Enjoy Marvel films	*Doesn't enjoy Marvel films*
Mean	8.025316456	7.416666667
Variance	11.89678676	12.08333333
Observations	79	12
Hypothesized Mean Differenc	0	
df	14	
t Stat	0.565718127	
P(T<=t) one-tail	0.290269995	
t Critical one-tail	1.761310136	
P(T<=t) two-tail	0.58053999	
t Critical two-tail	2.144786688	

Figure 8

The t-Test statistics provide three important values to discuss: t Stat, P(T⇐t) one-tail, and the t Critical two-tail. To better understand what each variable represents, we will start by discussing the significance of the p-value. For my t-Test, I received a p-value of 0.58, which is greater than the alpha value assigned of 0.05, which is typically used to determine "...whether or not our p-value is low enough to reject the null hypothesis" (Z. 2021). The null hypothesis for my data states that there is no statistically significant difference between those who enjoy or do not enjoy watching Marvel films and their knowledge of scientific literacy. It is generally considered that a p-value greater than 0.05 is statistically insignificant.

Therefore, this means that the null hypothesis cannot be rejected because the null hypothesis can be rejected only if the p-value is less than the alpha value, however, the condition is not fulfilled; therefore we cannot reject the null hypothesis. We can also reject the null hypothesis only if the t Stat (test statistics/t-value) value of 0.57 is greater than the t Critical two-tail value (Critical value) of 2.1, but this condition yet again, is not fulfilled, so we cannot reject the null hypothesis. Essentially, this means that my hypothesis is incorrect as there is no significant correlation between the students' scientific literacy and their enjoyment of watching Marvel films.

LIMITATIONS

Following my results, it is important to address the potential limitations that have inhibited the process and the effectiveness of my data. Three of my most dominant limitations included my sample size, student participation, and time constraints. While retrieving my data for the HFCI test scores and the enjoyment of Marvel films among students, I received an unexpectedly low number of students who did not enjoy Marvel films. As mentioned above in my results section, out of the 91 respondents from four AP Physics 1 classes, 79 students said that they enjoy watching Marvel films, but only 12 responded that they do not enjoy watching Marvel films. Due to the unproportioned number of students for the enjoyment of watching Marvel films, the randomness of my data was very limited, and it could have contributed to a less accurate data set, which might have skewed the results for my box and whiskers plot and my Two-Sample Independent t-Test samples. In addition to the limited sample size, it was made clear that not all students were able to participate in my research. Out of the eight students whose data was invalidated, a majority of them failed to finish the test, which limited the diversity of my sample population. One final limitation was the time constraints. For the AP Research course, we are only allowed a year to find our topic of interest, and then design and conduct our research. For example, if given additional time, a thorough analysis could have been done on my data by using the Two-Sample paired t-Test instead of a Two-Sample Independent t-Test, which would have been a better analysis method for my research paper.

AREAS FOR FUTURE RESEARCH

For future research, instead of sampling students after they received their physics lecture, I would sample students before they had any physics education. For my data analysis, as noted in the previous section, I would conduct a Two-Sample Paired t-Test, which would suit better for my research because "...in a paired sample t-test, each subject or entity is measured twice, resulting in *pairs* of observations" (Statistics Solutions). For example, instead of giving the HFCI test after learning about Newton's Three Laws, I would give the HFCI test both before and after learning about Newton's Three Laws, so that I can analyze the differences between the two groups and receive more precise and accurate results. This would be good for a long-term study, however, as mentioned above in my limitations, the time constraints would restrict my ability to conduct this research over the course of a year.

CONCLUSION

Learning science is not merely about teaching students how to memorize equations and administering complex scientific concepts; it is finding different ways to make sure students can resonate with different learning styles, which in turn helps each individual student engage better in class, ultimately enhancing their scientific literacy. I wanted to assess whether or not watching Marvel films -- one of the ways students can learn physics concepts -- created a relationship with students' scientific literacy. Using a variety of verified research instruments such as the HFCI test and the Two-Sample Independent t-Test, a total of 91 survey responses were collected from students at X High School to analyze how the student's knowledge of science, particularly Newton's Laws, correlate with their enjoyment of watching Marvel films. My results failed to prove my hypothesis significant, but through the results of the study, further research could be conducted to assess the data by using a Two-Sample Paired t-Test instead of utilizing a Two-Sample Independent t-Test to analyze the before and after results of the two groups over a longer duration of time. In addition, future research could also consider gender and/or grade level when selecting a pool for my population sample, as in my study, they were not considered, which could potentially enhance my results.

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