A Comparative Analysis of AP Sciences Examination Performances: Evidence of Increased Difficulty in AP Physics for the Period 2002 – 2024

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Abstract

The Advanced Placement (AP) program offered by the College Board is recognized for college preparatory education with a curriculum offering rigorous coursework geared towards equipping students with the essential skills and knowledge for admission and success in Institutions of Higher Educations (HEIs). The objective of this study is to determine if there is a significant difference between students' passing rates in AP Physics when compared to Biology, Chemistry, and Environmental Science for the past 23 years. AP annual score distribution dataset was ascertained from the College Board website, but lacking corresponding anonymized student profiles, which constrained the analysis to performance comparison across AP subjects. Friedman non-parametric test was performed followed by Wilcoxon Signed Ranks Test for pair comparison. The Friedman test revealed a significant effect on exam passes of 3s and higher in the sciences, χ^2 (3, n = 92) = 232.135, $p < .001$. Kendall's W test indicated a moderately high significant level of concordance between Physics 1 and Biology, and Physics 1 and Chemistry y for AP passes of 5s with Kendall's W = 0.682. Inferences from these results indicate that AP Physics is clearly different and more challenging than other sciences and possibly requires pedagogical interventions, and more innovative teaching and learning strategies that have the capability to impact both conceptual understanding and performance outcomes. These findings support earlier studies on the perceived difficulty in the teaching and learning of physics; this difficulty arises from rigorous mathematics, complexity of concepts, and deficiency in problem-solving skills. Further research is needed to understand the key factors that influences students' choices of AP subjects: demography of students and their performance, students' preparation methods, difficulty physics concepts, and instructors' assessment and feedback strategies. Since physics is a fundamental science requirement for matriculation into competitive engineering programs, and fewer students are taking AP physics when compared to the other AP sciences, more research is needed to help physics students develop greater conceptual understanding, physics reasoning and examination taking skills.

Introduction

Physics is one of the fundamental requirements for admission into several STEM programs in Higher Education Institutions [1]. Physics can be viewed as an admission requirement, or gate keeper for accessing STEM programs [1], then students who fail to select Physics, or failed Physics in high school will typically have trouble getting admission into their desired STEM undergraduate programs at high-ranking universities. However, Physics is a hard subject that several students struggle with [2], and "gaps in students' background knowledge", and competence in mathematics, and understanding the relationships between magnetic and electric fields accounts for some of the difficulties with the subject [3, p. 324].

A total of 101 pre-service Physics teachers completed four Physics courses on Mechanics (1 & 2), Electricity and Magnetism ranked electromagnetic waves (69.3%), Gauss's Law (62.4%), inductance (60.4%) and Faraday's Law (59.4%) as the five most difficult concepts from a list of 27 topics in total. In terms of the four subjects, Magnetism (41.6%) and Mechanics 2 (35.6%) where rank the two most difficult courses. When students were asked "Why do you think the first three subjects [topics/concepts] you have selected are the most difficult?" The pre-service teachers reported difficulty when thinking in 3-Dimensional ways and forming mental images of the concepts. Through content analysis, Şahin and Yağbasan reported that the four reasons (or themes) for the difficulty with physics were: subject content, student profiles, subject application and how the subject was taught [3, p. 22]. The future teachers themselves recognized the difficulty that comes with learning Physics and the challenges associated with a proper understanding of the subject.

The low uptake and overall performance in AP physics compared to other AP sciences for the past two decades is concerning, and we need to collaboratively and persistently work to improve AP physics uptake and performance. This paper seeks to evaluate the performance of students across four AP Sciences: Chemistry, Biology, Environmental Sciences, and Physics 1. How does the performance of students in AP Physics compare to the other selected sciences in the US? Is Physics more difficult than other sciences? Is this a myth or is there evidence to substantiate this belief? If so, what can we do to improve or sustain improvements in AP Physics performance in the US for the next decade?

Literature Review

The AP program started in response to the concern that the US was failing to prepare adequate students for the rigor of college level work. In 1951, Ford Foundation provided funding through the establishment of the Fund for the Advancement of Education (FAE). This financial support was aim at "better integrate high school and university curricula …[and] strengthening the transition from high school to college," the AP tests across 10 subject areas was birthed to assess high school students' readiness and preparation for college-level coursework. The AP program was taken over since 1955 by the not-for-profit College Board [4, p.2].

The AP program consist of subjects covering the arts, science humanities and mathematics is offered by the College Board as American-based nonprofit organization recognized as college preparatory education, with rigorous coursework geared to equipping students with essential skills and knowledge for successes at the postsecondary level [5]). The AP program was initially started in the US in the 1950s for a selected privilege group of students [6] but has been made available for approximately 80 percent of US Public schools [7]. AP courses are generally available in more affluent districts and are generally selected by high-achieving students with plans to attend college. Students with AP exam scores of 4s or 5s have higher GPAs in college and greater graduation rates when compared to non-AP participants. Students with AP Scores of 4s and 5s have a competitive admission selection advantage than students who have not taken or passed AP exams [8].

A correlational study was performed on 430 first-year students enrolled in standard university Physics 1 introductory calculus-based mechanics' course [9]. The study compared scores from the Force Motion Conceptual Evaluation (FMCE) compared to scores on AP physics and Math SAT respectively. The results indicated that students who had taken AP Physics had statistically significant predicted scores when compared to students who only completed a high school physics course. Burkholder and Wieman reported that students' scores in the undergraduate physics demonstrate a greater conceptual understanding of physics when compared to the students that did not take AP physics [9].

Early participation in AP courses in high schools "leads to higher scores on state exit exams … increased college attendance and completion rates" for all groups including traditional underserved and underrepresented groups [5, p. 1]. The performance of students on their AP exams is important to the students themselves, their parents, and their schools among other stakeholders. Students' performance on AP examinations is one of the major predictors of success in college [10]. Other predictors of students' success in higher colleges include maximum parental education, SAT score, high school GPA, number of AP exams scoring 3 or higher, first-year college GPA, and 4-year bachelor's degree completion [10]. The lack of early pedagogical intervention to improve AP physics can have significant implications on students' conceptual understanding and progress for both traditional and interdisciplinary engineering majors.

The fairness, reliability, difficulty level, and quality of assessment instruments can impact students' performance in any course at any level. Test results from Force Concept Inventory (FCI, n = 128) and Conceptual Survey of Electricity and Magnetism (CSEM, n = 67) were analyzed for two calculus-based college Physics courses between 2017 and 2024 using a 15 Predictor Variable priori models based on three question categories: verbal, diagrammatic, and complex. The findings indicated that the significant predictors of FCI posttest scores are complex kinematics, verbal Newton's third law, verbal force types, and complex first laws, with a regression model having a R^2 value of 37.8%. The Pretest and Posttest scores were positively correlated for diagrammic question types, but there was the verbal and complex questions type that were challenging to predict. The authors suggested that students' language skills or understanding of 'jargons' could potentially improve students' performance on the FCI test [11].

There are several concerns with how AP courses are delivered in the US, these include equitable access across students' socioeconomic backgrounds, enrollment gaps, state-level AP policies, course offerings variability across districts, and lack of evidence of AP programs preparation of students' post-secondary goals, and lack of mandatory enrollment of test takers in an AP program [12]. When students participate in an AP science program resulting in taking the science course, there is possible evidence that students increased their science skill and with a greater interest in pursuing a STEM related major in higher education [13]. The AP scoring details are represented in table 1 with recommendations for how students' score indicates their potential qualification for receiving college credit [14].

Table 1: AP Scoring

AP Exam Score	**Recommendation**	**College Course Grade Equivalent**
5	Extremely well qualified	A+ or A
4	Very well qualified	A-, B+, or B
3	Qualified	B-, C+, or C
2	Possibly qualified	----
1	No recommendation	----

The taking of AP science courses is not necessarily related to students' choice of pursuing a STEM major in college [3]. While the debate continues on the apparent limited access of the AP program across the US school districts, with concerns of inequitable distribution of the benefits of AP for all students, this paper will not be advancing the debate on access and effectiveness of the AP programs, or expansion of the program. Rather, the focus of this paper is to gain insights on the performance of students across science courses over the past two decades.

Research Question

Is there a significant difference between students' passing rates in AP Physics when compared to other sciences (Biology, Chemistry, and Environmental Science)?

Hypotheses

- $\boldsymbol{H_0}: \mu_{B5} = \mu_{C5} = \mu_{E5} = \mu_{P5}$
- $\boldsymbol{H_0}: \mu_{B4} = \mu_{C4} = \mu_{E4} = \mu_{P4}$
- $\boldsymbol{H_0}: \mu_{B3} = \mu_{C3} = \mu_{E3} = \mu_{P3}$

$\boldsymbol{H_1}$: At least one μ differs significantly from the others.

Post Hoc Comparison Hypotheses

- $\boldsymbol{H_0}: \mu_{P3-5} = \mu_{B3-5}$
- $\boldsymbol{H_0}: \mu_{P3-5} = \mu_{C3-5}$
- $\boldsymbol{H_0}: \mu_{P3-5} = \mu_{E3-5}$
- $\boldsymbol{H_1}$: At least one μ pair comparison differs significantly from the others.

Notes: For the hypothesis, the subscript letters represent the first letter of the science subjects, and the number represents the past rate, for instance c represents chemistry and E represents Environmental Science, 3- 5 represents a pass rate of C, B & A, respectively. For instance, the mean score for Biology with a past rate of 5 or A is represented by μ_{B5}.

Methods

AP annual score distribution dataset was ascertained from the College Board website, but the dataset lacks corresponding anonymized profiles of students, gender, ethnicity, maximum education of parents, and the number of AP subjects taken by each student, which constraint the analysis to performance comparison across subjects. The data is freely available to the public through the College Board. The complete dataset used in this analysis was from the period 2002 to 2024. The year 2025 AP score dataset was excluded because it contained missing data at the time of the analysis. The analysis used 95% confidence interval and 5% margin of error with actual reported *p* values as shown in the result and discussion sections.

This data was transferred and converted into Spreadsheet/Microsoft Excel and later exported into SPSS for analysis. The major assumption for this analysis is that all students sat four science subjects each year. However, students could have taken more or less AP subjects based on availability, selection, and readiness among other factors. Therefore, the analysis and results are consistent with the assumptions and should be interpreted within this constraint. In a study containing 442,346 students from 100 four-year US higher education institutions, the average number of AP examinations taken was 2.714 (or 3 AP subjects) during the period 2009 to 2012, except 2010 [10]. However, the report lacked the standard deviation for the average number of AP examinations taken, and only accounts for 62.16% of a maximum of 37 AP subjects, and no information on the frequency of AP sciences taken.

In this study, the test of normality was performed using Q-Q plots, histogram plots, Shapiro-Wilk Test, and skewness parameters. The Levene's test was performed to determine the equality of variance across subject groups. The following four assumptions: independence within groups, normality, homogeneity of variance, and continuous scale for the dependent variable prior to performing ANOVA. The assumptions were violated for conducting the One-Way Within-Subjects (repeated measures) ANOVA for obtaining significant differences between pass rates of physics compared to other sciences.

The alternative non-parametric test, Friedman Test, was performed followed by an alternative Post Hoc Test for pair comparison. Instead of the initially planned Tukey's Honestly Significant Difference (Tukey's HSD) for pair comparisons between physics and other sciences, the non-parametric Wilcoxon Signed Ranks Test was conducted to determine AP Sciences with statistically significant results. The Kendal Coefficient of Concordance was used to evaluate the level of agreement in pair comparison and the potential practical implications of the statistically significant results.

Results

Descriptive Statistics

Table 2 provides details on the average measures of central tendencies across AP Biology ($\mu_{B5} =$ 13.72, s_{B5}^2 =32.65), Chemistry ($\mu_{c5} = 14.45,\ s_{B5}^2 = 9.61$), Environmental Sciences ($\mu_{E5} =$ 9.16, $s_{E5}^2 = 1.5$), and Physics 1($\mu_{P5} = 11.34,\ s_{E5}^2 = 18.20$) for the period 2002 to 2024 representing 23 years of average percent distribution scores. The mean and variances from Table 2 are stated for the maximum pass rate of 5s that represents an A, while 4s represents a B and 3s represents a grade of C. The average kurtosis (-1.321, -0.582, -0.446) & and skewness (0.163, 0.485, and 0.533) in Table 2 indicates that the data is approximately normally distributed. Figure 1 indicates the mean comparison across the sciences with similar trends except for environmental science with a large increase of 24.5 % for passes with 4s when compared to passes 3s with 16.9% and 5s with 9.2% respectively

Table 2 indicates that the mean test takers per course range from highest to lowest were Biology ($\mu_B = 191{,}696,\ s_B^2$ =54,296), Chemistry ($\mu_C = 122{,}023,\ s_C^2$ =32,455), Environmental Sciences ($\mu_E = 114{,}099,\ s_E^2$ =61782) and Physics 1 (($\mu_{P1} = 104{,}314,\ s_{P1}^2$ =52, 169). The results in Table 2 indicate violation of normality results which led to non-parametric data analysis.

Kendall's W test was conducted to evaluate the agreement of AP pass scores among Physics 1 and each of the other three sciences. The determined mean ranks for Physics $\boldsymbol{\mu_{P5}} =\ 11.343\%$ and Biolog $\boldsymbol{\mu_{B5}}$ = 13.722% are given, the test statistic indicated Kendall's W = $0.682, \chi^2(1) =$

$15.696, p = .005$). These results suggest an alternative hypothesis with a moderately high significant level of concordance between Physics and Biology for AP passes of 5s.
Kendall's W test was conducted among Physics 1 ($\mu_{P5} = 11.343\%$) and Chemistry ($\mu_{C5} = 14.452\%$), the test statistic indicated Kendall's W = $0.682, \chi^2(1) = 21.000,\ p = .00044$). These results suggest an alternative hypothesis with a moderately high significant level of concordance between Physics 1 and Chemistry for AP passes of 5s. The test statistic for Physics 4s ($\mu_{P4} = 17.487\%$ and Biology (μ_{B4}+= 20.226%) indicated Kendall's W = $0.319, \chi^2(1) = 7.348,\ p = .002$). These results suggest an alternative hypothesis with a fairly significant level of concordance between Physics 1 and Chemistry for students obtaining 4 or higher AP passes. The test statistic for Physics 1 ($\mu_{P4} = 17.487\%$) and Environmental Science (μ_{E4}+= 24.461%) indicated Kendall's W = $1.000, \chi^2(1) = 23.000.\ p = .002$). These results suggest an alternative hypothesis with a perfectly significant level of concordance between Physics 1 and environmental sciences for students obtaining 4s in AP passes. The test statistic for Physics 3s+ ($\mu_{P3+} = 53.165\%$) and Biology 3s+($\mu_{B3+} = 60.500\%$) indicated Kendall's W = $0.229, \chi^2(1) = 5.261,\ p = .005$). These results suggest an alternative hypothesis with a fairly significant level of concordance between Physics 1 and Chemistry for students obtaining 3 or higher AP passes.

Table 2. Descriptive Statistics of Four AP Sciences

Course		**5s**	**4s**	**3s**
Biology	Mean	13.722%	20.226%	26.122%
	N	23	23	23
	Std. Deviation	5.71409%	2.63632%	7.81897%
	Std. Error of Mean	1.191%	0.550%	1.630%
	Variance	32.651	6.950	61.136
	Kurtosis	-1.826	-0.598	-1.385
	Skewness	-0.375	-0.812	-0.053
Chemistry	Mean	14.452%	18.557%	24.113%
	N	23	23	23
	Std. Deviation	3.100%	3.007%	3.592%
	Std. Error of Mean	0.646%	0.627%	0.749%
	Variance	9.613	9.044	12.903
	Kurtosis	-1.357	5.099	-0.400
	Skewness	-0.319	2.302	0.365
Environmental Science	Mean	9.157%	24.461%	16.887%
	N	23	23	23
	Std. Deviation	1.225%	1.970%	1.805%
	Std. Error of Mean	0.256%	0.411%	0.376%
	Variance	1.502	3.881	3.258

Course		5s	4s	3s
	Kurtosis	0.406	0.261	-0.772
	Skewness	0.681	0.622	-0.410
Physics1	Mean	11.343%	17.487%	24.339%
	N	23	23	23
	Std. Deviation	4.266%	1.578%	4.046%
	Std. Error of Mean	0.88950%	0.32899%	0.84369%
	Variance	18.198	2.489	16.372
	Kurtosis	-1.526	1.006	-1.529
	Skewness	-0.267	-1.075	-0.254

Table 3 indicates that the total students that passed AP courses with 5s, 4s, and 3s were 12.2%, 20.8%, and 22.9% respectively. Table 4 indicates that the average Test Takers for the four selected sciences was 133,033 with Biology leading at 44.0% above Chemistry 8.3% below, Environmental Science, 14.2% below and Physics 1 with the lowest Test Takers of 21.6% below the mean when compared to the other sciences.

Table 3. Summary Descriptive Statistics of Science Courses

Course		5s	4s	3s
Total	Mean	12.168%	20.183%	22.865%
	N	92	92	92
	Std. Deviation	4.401%	3.541%	5.941%
	Std. Error of Mean	0.459%	0.369%	0.619%
	Variance	19.373	12.538	35.301
	Kurtosis	-1.321	-0.582	-0.446
	Skewness	0.163	0.487	0.533

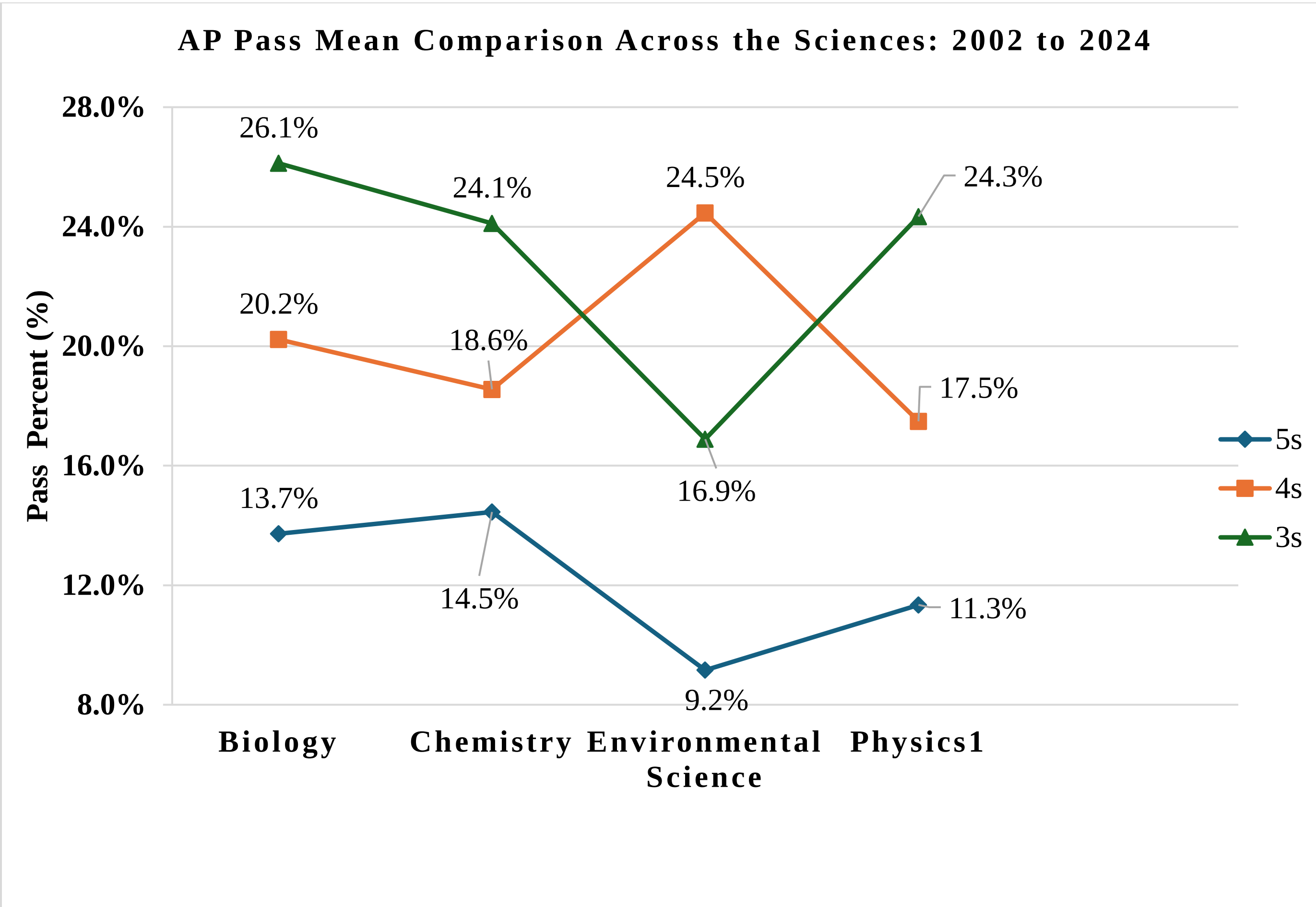

Figure 1. Mean Comparison Across AP Sciences

Table 4. Average Test Takers per Subject

Course	Mean Test Takers	N	Std. Deviation	Variance	Std. Error of Mean	Sum
Biology	191696	23	54294	2947878862	11321	4409004
Chemistry	122023	23	32455	1053332737	6767	2806539
Environmental Science	114099	23	61785	3817327985	12883	2624281
Physics1	104314	23	52169	2721558036	10878	2399212
Total	133033	92	61218	3747651821	6382	12239036

Discussions

The Test Takers for the Sciences with passes 3 – 5 per year for the period 2002 to 2024 indicated that biology remains the leading science subject, while physics remains the lowest uptake subject except the initial period 2002 to 2009 when Environmental Sciences AP was introduced. AP Environmental Science was recommended to be a core curriculum instead of an elective, then it received "widespread adoption … as a required subject for high school" [15, p. 42].

The mean score for Physics pass with 5s for the 23-year period was ranked third as indicated in figure 1 with 24.3 %; pass with 4s was ranked fourth with 17.5% and pass with 3s was ranked fourth with 11.3%. The overall ranking of Physics 1 is third place with a mean of 53.17% and 9 % standard deviations. Physics 1 mean percent distribution for the period compared to other sciences indicates the difficulty level of Physics based on the performance data without consideration to other factors.

The data for Biology, Chemistry, and Physics based on the results in Table 5 for passes of 3s and higher indicates non-normality except for Environmental Science. Since the normality results indicate violation of the assumption for performing One-Way ANOVA Repeated measures, the alternative non-parametric Friedman Test was performed with descriptive statistics and mean ranking results shown in Table 6. "The nonparametric Friedman's test is the alternative nonparametric procedure to the parametric ANOVA for the repeated measures one-way ANOVA" [16, p. 2367]. The Friedman test revealed a significant effect on exam passes of 3s and higher in the sciences, $\chi^2(3, n = 92) = 232.135, p < .001$. The median indicated that pass score was highest in the 3s (Md = 22.150) followed by 4s (Md =19.250) and followed by 5s (Md = 11.30) as expected in terms of overall distribution of scores.

Kendall's W test was conducted to evaluate the agreement of AP pass scores among Physics 1 and each of the other three sciences (Biology, Chemistry and Environmental Sciences). These was a moderately high significant level of concordance between Physics 1 and Biology, and Physics 1 and Chemistry y for AP passes of 5s with Kendall's W = 0.682. There was a fairly significant level of concordance between Physics 1 and Chemistry for students obtaining 4 or higher AP passes, Kendall's W = 0.319. There was a perfectly significant level of concordance between Physics 1 and Environmental Sciences for students obtaining 4s in AP passes with Kendall's W = 1.000. There was a fairly significant level of concordance between Physics 1 and Chemistry for students obtaining 3s or higher AP passes. All these results indicate strong agreement between Physics and other selected sciences.

AP Physics is clearly different and more challenging than other sciences and possibly requires more innovative and non-traditional teaching strategies that have the capability to impact performance outcomes. Physics is regarded as a "complex science discipline" and is often "challenging for other learners to learn" and should embrace both non-digital and technology-aided approaches teaching strategies [17, p. 112].

Table 5. Normality tests per Group

		Tests of Normality					
		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
AP Courses	Pass	Statistic	df	Sig.	Statistic	df	Sig.
Biology	5s	0.227	23	0.003	0.790	23	0.000
	4s	0.177	23	0.061	0.876	23	0.008
	3s	0.137	23	.200*	0.915	23	0.053
	3s+	0.215	23	0.007	0.873	23	0.007
Chemistry	5s	0.166	23	0.099	0.916	23	0.055
	4s	0.320	23	0.000	0.689	23	0.000
	3s	0.123	23	.200*	0.962	23	0.503
	3s+	0.471	23	0.000	0.249	23	0.000
Environmental Sciences	5s	0.172	23	0.075	0.946	23	0.239
	4s	0.194	23	0.024	0.932	23	0.120
	3s	0.119	23	.200*	0.947	23	0.248
	3s+	0.135	23	.200*	0.951	23	0.309
Physics 1	5s	0.168	23	0.091	0.894	23	0.019
	4s	0.168	23	0.089	0.912	23	0.044
	3s	0.215	23	0.007	0.887	23	0.014
	3s+	0.280	23	0.000	0.801	23	0.000

Table 6. Friedman Test – Descriptive Statistics and Mean Rank

Pass	N	Percentiles			
		25th	50th (Median)	75th	Mean Rank
5s	92	8.800%	11.300%	16.375%	1.14
4s	92	17.525%	19.250%	23.100%	2.21
3s	92	18.500%	22.150%	27.200%	2.65
3s+	92	50.400%	55.300%	60.775%	4.00

Is there a significant difference between students' passing rates in AP Physics when compared to the AP sciences: Biology, Chemistry, and Environmental Science? The Friedman test results in Table 6 indicated that there was a statistically significant difference between Physics and at least one of the other AP sciences, but not pair comparison. The Wilcoxon Signed Rank Test results in Table 7 indicated a statistically significant difference in AP pass scores between Physics and Biology with passes 3 or higher ($z = -2.388$, $p = 0.017$, Md = 9.92) students obtaining a pass of 3 or higher, for all sciences with pass scores of 5, Biology ($z = -3.057$, $p = 0.002$, Md = 7.50) with pass score 4, and Environmental Sciences with pass scores 3 ($z = -4.198$, $p = 0.00003$, Md = 0.0) and 4 ($z = -4.200$ $p = 0.00003$, Md = 0.0) respectively as shown in Table 8. Further details on hypothesis Tests and Kendal W results are provided for pair comparison of science courses at different pass levels (5s, 4s, and 3s) in Table 9 in the Appendix section.

Conclusion

The non-parametric Friedman test results indicate a statistically significant difference between Physics and other AP sciences, $\chi^2(3, n = 92) = 232.135, p < .001)$. The Post Hoc tests using the Wilcoxon Signed Ranks Test results in seven of the twelve pair comparisons shown in Table 8 indicated statistically significant differences between physics and biology, physics and chemistry and physics and environmental sciences. Kendall's coefficient of concordance for all three selected sciences compared to Physics 1with passes of 3s and higher indicated fairly significant concordance and perfectly significant agreement between Physics 1 and Environmental Sciences for passes with 4s. These results indicate that physics seems to be harder than the other sciences, especially with a low number of students sitting and passing AP physics when compared to other sciences. These findings support prior perceived difficulty in the teaching and learning of physics; this difficulty arises from "conceptual complexity and mathematical demand" [18, p.1388]. The integration of engineering design problems in physics laboratories could help physics students develop mathematical thinking, design-based thinking, science-based thinking, and metacognitive reflection with appropriate scaffolding [19]. Other strategies include gamification teaching strategy for high school physics, results from experimental studies revealed that high school students are "more satisfied and connected in a gamified teaching environment… and solve [physics] problems more easily" [20, p.14]

The number of students enrolled in AP sciences (Biology, Chemistry, Environmental Sciences and Physics 1) over the past 23 years has steadily increased, while the average percent passing for all sciences is on the decline except for Physics 1. Since the demand for Science, Technology, Engineering and Mathematics (STEM) graduates is rising high [21], the need for greater enrollment and success in AP sciences can help to satisfy the demand. Since AP enrollment in high schools is generally optional, how can we increase both enrollment and pass across all sciences? How can we develop more effective pedagogies for the teaching and learning of both AP physics and undergraduate engineering physics courses?

Practical Implications

This study indicates that students taking first year college physics and engineering courses could potentially struggle because of low performance in AP physics, underdeveloped problem-solving skills, and lack of conceptual understanding of fundamental physics concepts. To potentially improve students' performance in Physics, students should employ the following lessons learnt from 34 students who sat AP Physics 1 and felt that their experience might have been different if they had: (1) a positive attitude towards learning physics, (2) intentionally read course materials prior to class, (3) seek help early from their instructor, (4) complete extra practice problems, and (5) work collaboratively on homework problems within their cohorts [22].

Both students and instructors must be cognizant of the periodic changes that occur with Physics curriculum and examinations. For instance, AP Physics 1 syllabus includes 'Fluid', the eight unit which took effect as of the 2024-2025 academic period, the examination is 3-hours and is administered into two 90-minutes sections: approximately 50 multiple-choice questions, and four free-response questions that typically includes "lab-based" and "math-skills" [23, p. 54].

Instructors teaching AP physics, engineering physics, sciences and engineering should review, reflect and innovate new pedagogies for improving students' performance, provide scaffolding and conceptual understanding of targeted curriculum content. The evidence from traditional lecture-based pedagogies used in Physics is limited in developing scientific reasoning, real world problem-solving skills, and deep conceptual understanding of the subject [24]. Low performing students' needs appropriate monitoring and calibrated feedback to better monitor their own learning of course material [25], evaluates problem difficulty and provides rational for their solution [26], so students can be empowered to accurately predict their performance on examinations. The "Ways of Thinking in Engineering Design-based Physics (WoT4EDP)" can be implemented in AP Physics to evaluate how students think in classroom tasks such as solving physics problems in tutorial sections, to include special emphasis on metacognition reflection and computational thinking for the pedagogical goals: mathematical-based thinking, integrative thinking and problem solving [27].

Future Research

There are several questions that I would like to explore coming out of this study; these include: What are the major factors that influence students' choices of AP subjects? Is there a significant difference between physics and other sciences by virtue of gender, ethnicity, or race? How do students prepare for AP subjects when compared to other standardized tests such as SAT. What Physics concepts are students struggling with? What percent of students benefit from exemption or reduced total credit requirements during their first year of college? How do students with AP performance compared to non-AP students during the first two years of college? What pedagogies are most useful to teach Physics topics that students repeatedly struggle with?

The lack of problem-solving skills in AP physics could have negative implications for undergraduate physics students if not addressed. Since students are struggling with well-defined problems, how will they solve ill-structured problems in authentic engineering contexts.

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Appendices

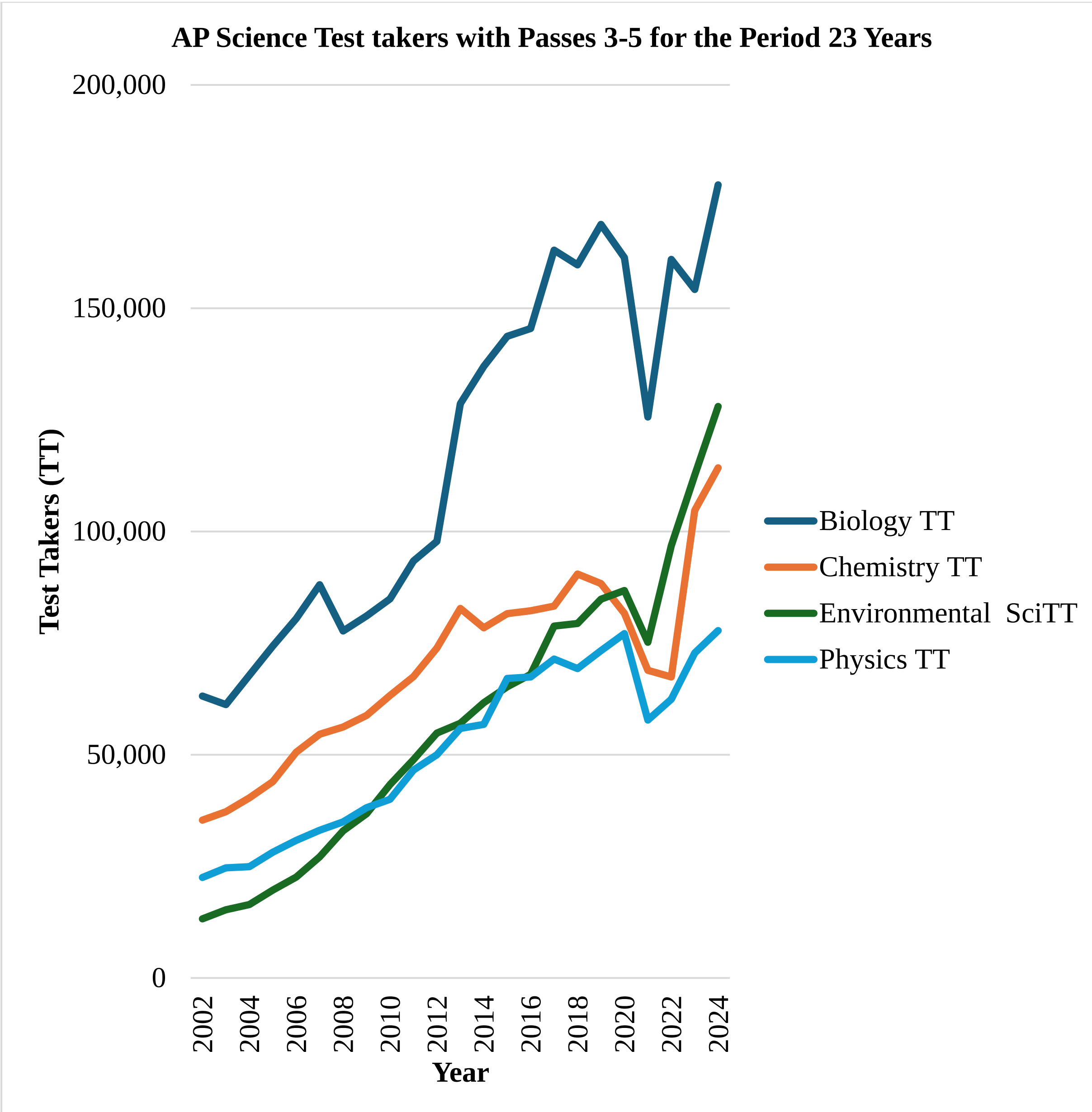

Figure 2. AP Test Takers for the Sciences with passes 3 – 5

Table 7. Wilcoxon Signed Ranks Test Results Comparing Physics with other sciences and Kendall's Coefficient of Concordance

Test Statistics[a]												
	Bio 3s+ - Phys1_3s+	Chem 3s+ - Phys1_3s+	Enviro_Sci 3s+ - Phys1_3s+	Bio 5s - Phys1_5s	Chem 5s - Phys1_5s	Enviro_Sci 5s - Phys1_5s	Bio 4s - Phys1_4s	Chem 4s - Phys1_4s	Enviro_Sci 4s - Phys1_4s	Bio 3s - Phys1_3s	Chem 3s - Phys1_3s	Enviro_Sci 3s - Phys1_3s
Z	-2.388[b]	-1.673[b]	-1.780[c]	-2.829[b]	-3.514[b]	-2.389[c]	-3.057[b]	-1.738[b]	-4.200[b]	-1.293[b]	-.411[c]	-4.198[c]
p	0.017	0.094	0.075	0.005	0.000	0.017	0.002	0.082	0.000	0.196	0.681	0.000
a. Wilcoxon Signed Ranks Test; b. Based on negative ranks; c. Based on positive ranks; *p* = Asymp. Sig. (2-tailed)												

Table 8a. Wilcoxon Signed Ranks Test

	Bio 3s+ - Phys1_3s+				Chem 3s+ - Phys1_3s+				Enviro_Sci 3s+ - Phys1_3s+				Bio 5s - Phys1_5s			
	Negative Ranks	Positive Ranks	Ties	Total	Negative Ranks	Positive Ranks	Ties	Total	Negative Ranks	Positive Ranks	Ties	Total	Negative Ranks	Positive Ranks	Ties	Total
N	6[a]	17[b]	0[c]	23	12[d]	11[e]	0[f]	23	13[g]	10[h]	0[i]	23	2[j]	21[k]	0[l]	23
Mean Rank	9.92	12.74			6.92	17.55			15.12	7.95			22.50	11.00		
Sum of Ranks	59.50	216.50			83.00	193.00			196.50	79.50			45.00	231.00		

Table 8b. Wilcoxon Signed Ranks Test

	Chem 5s - Phys1_5s				Enviro_Sci 5s - Phys1_5s				Bio 4s - Phys1_4s				Chem 4s - Phys1_4s			
	Negative Ranks	Positive Ranks	Ties	Total	Negative Ranks	Positive Ranks	Ties	Total	Negative Ranks	Positive Ranks	Ties	Total	Negative Ranks	Positive Ranks	Ties	Total
N	2[m]	21[n]	0[o]	23	15[p]	8[q]	0[r]	23	5[s]	18[t]	0[u]	23	5[v]	11[w]	7[x]	23
Mean Rank	11.25	12.07			14.43	7.44			7.50	13.25			6.90	9.23		
Sum of Ranks	22.50	253.50			216.50	59.50			37.50	238.50			34.50	101.50		

Table 8c. Wilcoxon Signed Ranks Test

	Enviro_Sci 4s - Phys1_4s				Bio 3s - Phys1_3s				Chem 3s - Phys1_3s				Enviro_Sci 3s - Phys1_3s			
	Negative Ranks	Positive Ranks	Ties	Total	Negative Ranks	Positive Ranks	Ties	Total	Negative Ranks	Positive Ranks	Ties	Total	Negative Ranks	Positive Ranks	Ties	Total
N	0[y]	23[z]	0[aa]	23	12[ab]	11[ac]	0[ad]	23	13[ae]	10[af]	0[ag]	23	23[ah]	0[ai]	0[aj]	23
Mean Rank	0.00	12.00			7.96	16.41			11.65	12.45			12.00	0.00		
Sum of Ranks	0.00	276.00			95.50	180.50			151.50	124.50			276.00	0.00		

Table 9: Hypothesis Test and Kendall's W Results Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision	Kendall's W	Test Statistic
1	The median differences between Bio 5s and Phys1_5s equals 0.	Related-Samples Sign Test	<.001[c]	Reject the null hypothesis.	0.682	15.696
		Related-Samples Wilcoxon Signed Rank Test	0.005			
2	The median differences between Phys1_5s and Chem 5s are equal to 0.	Related-Samples Sign Test	<.001[c]	Reject the null hypothesis.	0.682	21
		Related-Samples Wilcoxon Signed Rank Test	0.000			
3	The median differences between Phys1_5s and Enviro_Sci 5s equal to 0.	Related-Samples Sign Test	.210[c]	Retain the null hypothesis.	0.093	2.130
		Related-Samples Wilcoxon Signed Rank Test	0.017			
4	The median differences between Phys1_3s+ and Bio 3s+ equal to 0.	Related-Samples Sign Test	.035[c]	Reject the null hypothesis.	0.229	5.261[a]
		Related-Samples Wilcoxon Signed Rank Test	0.017			
5	The median differences between Phys1_3s+ and Chem 3s+ equal to 0.	Related-Samples Sign Test	1.000[c]	Retain the null hypothesis.	0.002	.043[a]
		Related-Samples Wilcoxon Signed Rank Test	0.094			

Table 9: Hypothesis Test and Kendall's W Results Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision	Kendall's W	Test Statistic
6	The median differences between Phys1_3s+ and Enviro_Sci 3s+ equal to 0.	Related-Samples Sign Test	.678[c]	Retain the null hypothesis.	0.017	.391[a]
		Related-Samples Wilcoxon Signed Rank Test	0.075			
7	The median differences between Phys1_4s and Chem 4s equal to 0.	Related-Samples Sign Test	.210[c]	Retain the null hypothesis.	0.098	2.250[a]
		Related-Samples Wilcoxon Signed Rank Test	0.082			
8	The median differences between Phys1_4s and Bio 4s equals 0.	Related-Samples Sign Test	.011[c]	Reject the null hypothesis.	0.319	7.348[a]
		Related-Samples Wilcoxon Signed Rank Test	0.002			
9	The median of differences between Phys1_4s and Enviro_Sci 4s equals 0.	Related-Samples Sign Test	<.001[c]	Reject the null hypothesis.	1.000	23.000[a]
		Related-Samples Wilcoxon Signed Rank Test	0.000			
10	The median differences between Phys1_3s and Bio 3s equals 0.	Related-Samples Sign Test	1.000[c]	Retain the null hypothesis.	0.002	.043[a]
	The median differences between Phys1_3s and Bio 3s equals 0.	Related-Samples Wilcoxon Signed Rank Test	0.196			

Table 9: Hypothesis Test and Kendall's W Results Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision	Kendall's W	Test Statistic
11	The median differences between Phys1_3s and Chem 3s equal to 0.	Related-Samples Sign Test	.678[c]	Retain the null hypothesis.	0.017	.391[a]
	The median differences between Phys1_3s and Chem 3s equal to 0.	Related-Samples Wilcoxon Signed Rank Test	0.681			
12	The median differences between Phys1_3s and Enviro_Sci 3s are equal to 0.	Related-Samples Sign Test	<.001[c]	Reject the null hypothesis.	1.000	23.000[a]
	The median differences between Phys1_3s and Enviro_Sci 3s are equal to 0.	Related-Samples Wilcoxon Signed Rank Test	0.000			

Notes:
a. The significance level is .050.,
b. Asymptotic significance is displayed.
c. Exact significance is displayed for this test.