Gender Differences in Physics: A Comparative Study of Persistence

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We investigate the difference in persistence between male and female students while taking a physics course. We collected the data from three consecutive workshops on various topics of physics. After plotting the number of participations against the number of days attended, we calculate the decay rates for both male and female students on each workshop and compared them on a bar diagram. The comparative bar diagram of decay rates clearly shows that the decay rates of male students were significantly higher than that of female students. This leads us to the conclusion that the female students are more persistent than male students while taking a physics course.

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I. INTRODUCTION

It is a well-documented fact that the disciplines of science, technology, engineering and math (STEM) are pre-dominated by male students. Agreeing to some studies, women in physics only comprise approximately 19% of all undergraduate and graduate students [1-5]. Some other studies indicate that women show lower levels of conceptual knowledge than men in both beginning and ending of introductory physics courses [6,7]. According to that research, women show less involvement in learning and problem solving [7]. These gender differences increase, for both conceptual knowledge and involvement, along with the evolution of the course [6,7]. In the study of Kost-Smith [8], she found that women entered introductory physics courses with lower self-efficacy than men, and this disparity also increased along with the development of the course. In lecture-based physics courses, Sawtelle *et al.* [9] obtained the same result, as did Cavallo *et al.* [10] and Lindstrom and Sharma [11]. Another investigation [12] says, women exhibit less expert attitude than men.

As a part of a non-profit educational institution, Community of Physics, we have organized and conducted several workshops focusing on diverse topics in physics and mathematics. In the beginning of every workshop, we have seen that the male participants exceptionally outnumber the female participants. After the first day, the numbers of the participants in both groups start to decline, and on the last day, the number of female students and the number of male students become nearly equal. This consistent behavior of the students piqued our curiosity and lead us to hypothesize that the female students show a higher persistence than the male students. Thus, we were inclined to conduct a formal research to check the validity of our hypothesis.

II. METHODS

A. COLLECTION OF DATA

We administered our study in three workshops. Each of the workshops explored the physical and mathematical aspects of a distinct field of interest. The first one was on vector calculus, the second one was on Newtonian mechanics, and the third one was on classical electromagnetism. All of the participants were undergraduate students of various disciplines of the physical sciences and engineering from several Bangladeshi universities. Participation data were collected on a daily basis.

The inaugural workshop was labeled as *1st Workshop on Vector Calculus (WVC1)*. The workshop covered vector algebra, single-variable differential and integral calculus, multi-variable and parametric functions, partial derivatives, multi-variable integral calculus, fundamental theorems of vector calculus, vector analysis on curved manifolds, Cartesian tensors and Maxwell's equations as an application of vector calculus. We prepared course materials following *Calculus* by Anton *et al.* [13], *Calculus* by Strauss *et al.* [14], Banchoff, and Lovett's *Differential Geometry of Curves and Surfaces* [15], and *Vector Analysis* by Spiegel and Lipschutz [16]. *WVC1* was a six-day workshop. It ran for six days starting from 8:30 am to 5:00 pm with a one-hour break.

On the starting day, there were 89 participants, of whom 66 were male and 17 were female. Of the total 89 participants, 21 (25.3%) were from physics, 13 (15.7%) were from mathematics, 20 (24.1%) were from electrical engineering, 9 (10.8%) were from computer science, 6

(7.2%) were from communication engineering, 4 (4.8%) were from civil engineering, and 11 (13.3%) were from mechanical and other engineering disciplines.

The epithet of the second workshop was *1st Workshop on Classical Mechanics: From Newton to Lagrange (WCM1)*. This workshop covered preliminary mathematical tools, Newton's laws, projectile motion, drag force, conservation of momentum, conservation of energy, oscillation (simple, damped & damped-driven), Newtonian gravity, Kepler's laws, mechanics in non-inertial frames, D'Alembert's principle and Lagrange's equation. The course materials were prepared using Jefferson and Beadsworth's *Further Mechanics* [17], *Introduction to Classical Mechanics: With Problems and Solutions* by Morin [18], *Classical Mechanics* by Goldstein *et al.* [19], and Taylor's *Classical Mechanics* [20]. It was a five-day workshop. Starting from 9:00 am, the workshop ran up to 5:30 pm with a one-hour break in between.

On the starting day of the workshop, there were 57 participants, of whom 47 were male and 10 were female. Of the total 57 participants, 15 (26.3%) were from physics, 8 (14.0%) were from mathematics, 5 (8.8%) were from chemistry, 11 (19.3%) were from electrical engineering, 6 (10.5%) were from computer science, 5 (8.8%) were from mechanical engineering, and 4 (7.0%) were other engineering students.

The third workshop was termed as *1st Workshop on Classical Electromagnetism (WEM1)*. The workshop explored vector analysis, Helmholtz theorem, electrostatic field equations, electrostatic force and energy, Poisson's and Laplace's equation, Green's function, polarization, dielectric medium, magnetostatic field equations, magnetostatic force and energy, magnetization, magnetic materials, Maxwell's equations, conservation laws in electromagnetism, potential formulation, electromagnetic waves and special theory of relativity. We used Griffiths' *Introduction to Electrodynamics* [21], Zangwill's *Modern Electrodynamics* [22], and Franklin's *Classical Electromagnetism* [23] in preparing course materials. With a one-hour break, the workshop ran from 8:00 am to 6:00 pm for five days.

On the starting day, there were 38 participants, of whom 28 were male and 10 were female. Of the total 38 participants, 12 (31.6%) were from physics, 3 (7.9%) were from chemistry, 2 (5.3%) were from mathematics, 9 (23.7%) were from electrical engineering, 4 (10.5%) were from mechanical engineering, 3 (7.9%) were from computer science, 2 (5.3%) were from chemical engineering, and 3 (5.3%) were from other engineering disciplines.

As our data represent a diverse body of students of a multitude of backgrounds, it is highly likely, that our data is little touched by random fluctuation. Participants accepted to fill a form by their-selves to confirm their presence on the day of the workshop.

B. ANALYSIS OF DATA

The collected data were first tabulated in a spreadsheet using Microsoft Excel 2016. Then the data were sorted to identify the number of the participants of different backgrounds, as presented in the previous section. Further sorting was carried out to identify male and female participants. For each workshop, a set of male and female participation data were obtained.

Then we plot the number of the participants attending against the number of days for each set of data, and fit each with exponential curves. All of the curves had a negative valued exponent showing a decay-like behavior. We call the values of the exponents as decay rates. Thus, from each workshop data, we obtained one decay rate for male participants and another decay rate for female participants. Then we compare the decay rates of male and female participants in a single bar diagram for each workshop.

III. DATA AND RESULTS

The result of our investigation will be presented for each workshop individually in *FIG. 1-FIG. 6,* and then the combined comparison will be presented in *FIG. 7*. In all the plots, data points were fitted with exponential curves.

A. 1ST WORKSHOP ON VECTOR CALCULUS (WVC1)

In *WVC1*, there were 66 male participants who were present for at least 1 day and there were only 2 male participants with sustained participation for all the six days of the workshop. *FIG. 1* shows the number of the male participants against the number of days attended. The obtained decay rate was 0.642*.

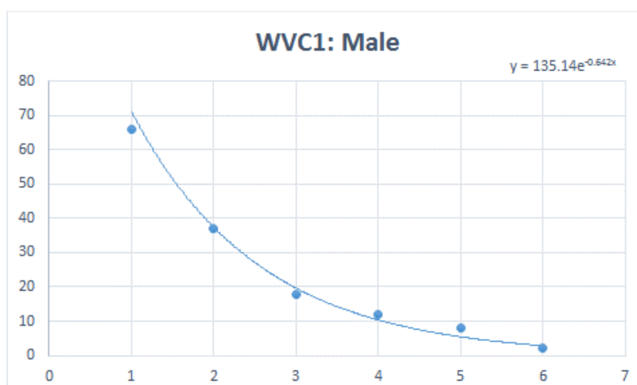

FIG. 1. Number of participants vs. number of days attended for male participants in 1st Workshop on Vector Calculus (WVC1).

On the other hand, there were 17 females who participated at least 1 day and there were only 3 female participants who persisted through all six days of the workshop. *FIG. 2* shows the number of the female participants against the number of days attended. The obtained decay rate was 0.320*. This decay rate of the female participants is 50.2% lower than the decay rate of the male participants of the same workshop.

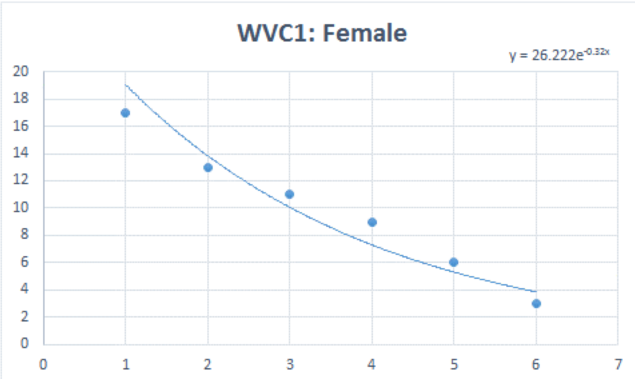

FIG. 2. Number of participants vs. number of days attended for female participants in 1st Workshop on Vector Calculus (WVC1).

B. 1ST WORKSHOP ON CLASSICAL MECHANICS: FROM NEWTON TO LAGRANGE (WCM1)

In *WCM1*, there were 47 male participants who stayed for at least 1 day and there were 8 male participants who continued through all five days of the workshop. *FIG. 3* shows the number of the male participants against the number of days attended. The obtained decay rate was 0.442[*].

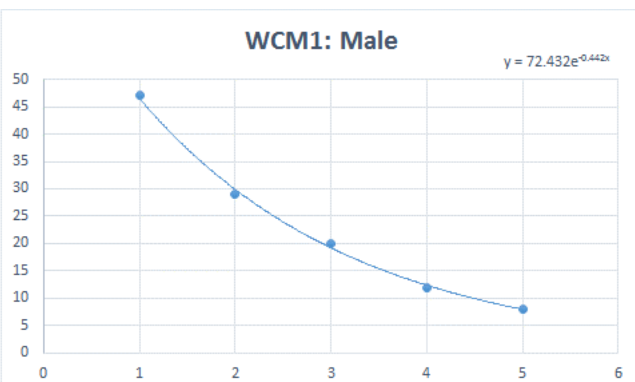

FIG. 3. Number of participants vs. number of days attended for male participants in 1st Workshop on Classical Mechanics: From Newton to Lagrange (WCM1).

In contrast, there were 10 female participants who participated for at least 1 day and there were only 3 female participants who joined us on all the five days of the workshop. *FIG. 4* shows the number of the female participants against the number of days attended. The obtained decay rate was 0.310[*]. This decay rate of the female participants is 29.9% lower than the decay rate of the male participants of the same workshop.

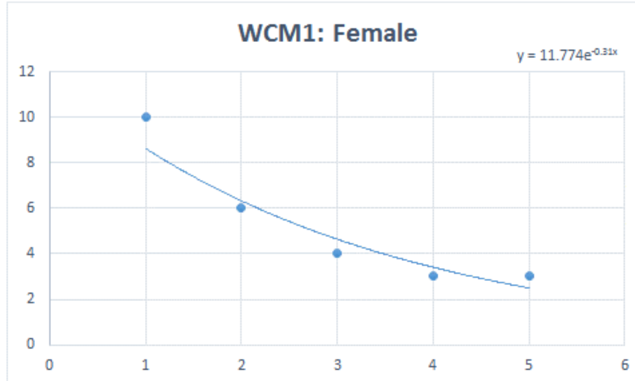

FIG. 4. Number of participants vs. number of days attended for female participants in 1st Workshop on Classical Mechanics: From Newton to Lagrange (WCM1).

C. 1ST WORKSHOP ON CLASSICAL ELECTROMAGNETISM (WEM)

In *WEM1*, 28 male participants were present for at least a day, while only 6 males could sustain their interest throughout the five days of the workshop. *FIG. 5* shows the number of the male participants against the number of days attended. The obtained decay rate was 0.377[*].

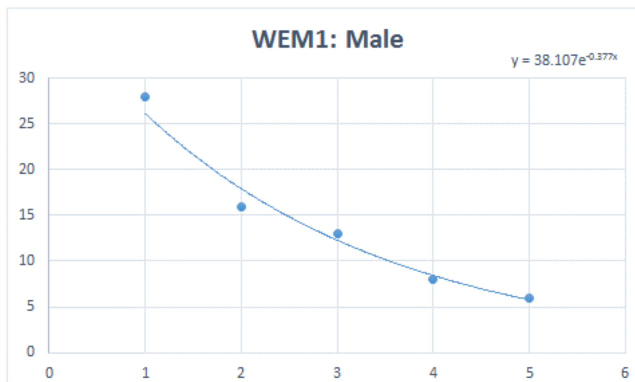

FIG. 5. Number of participants vs. number of days attended for male participants in 1st Workshop on Classical Electromagnetism (WEM1).

Then again, we had a population of 10 females on the first day, which dwindled to 3 over the course of the workshop. *FIG. 6* shows the number of the female participants against the number of days attended. The obtained decay rate was 0.297[*]. This decay rate of the female participants is 21.2% lower than the decay rate of the male participants in the same workshop.

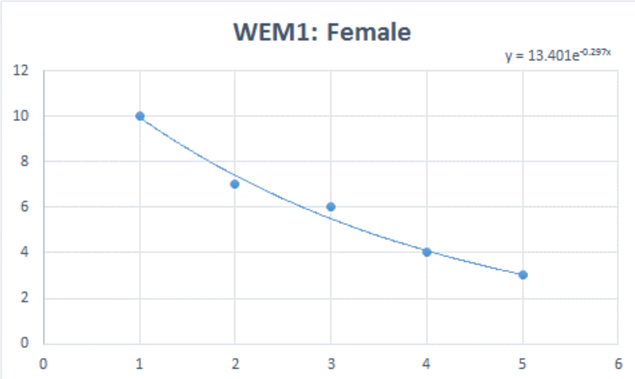

FIG. 2. Number of participants vs. number of days attended for female participants in 1st Workshop on Classical Electromagnetism (WEM1).

D. COMPARISON BETWEEN THE DECAY RATES OF MALE AND FEMALE PARTICIPANTS

In *FIG. 7*, we show the comparison between the decay rates of male and female participants graphically. It shows that in each workshop, the decay rate of the female participants is significantly lower than that of the male participants at a tolerance of 20%.

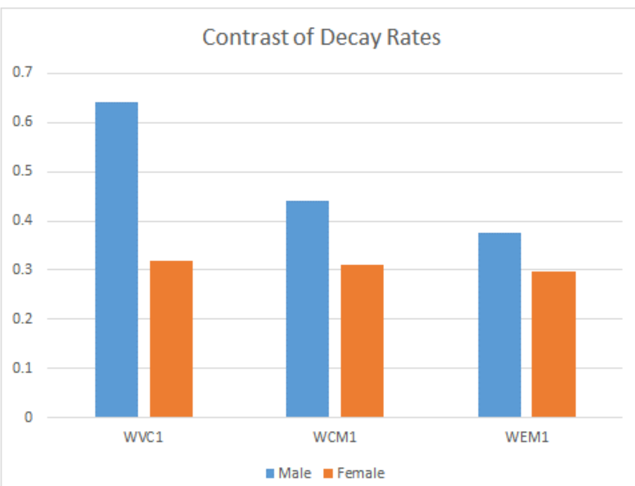

FIG. 3. Contrast of decay rates for male and female participants for each workshop.

IV. DISCUSSION AND CONCLUSIONS

In our study, the three workshops exhibited different values of the decay rates for both male and female participants. While the decay rates of the male participants varied wildly in three workshops, the decay rates of the female participants remained almost stable. The decay rates could vary due to other external factors [24] like transportation facility to the location or the workload in the workshop. But the key point is to notice that the decay rate of the male participants always exceeded the decay rate of the female participants in a single workshop. Therefore, we conclude that the female students are more persistent than male students while taking a physics course. Previously, McCormick, Barthelemy, and Henderson had produced similar results in their study [25].

Another important point is that as the workload in the three consecutive workshops gradually increased, the difference between the decay rates diminished. It could be possible that the increased amount of workload decreases the gender gap, but it requires further study to be proven.

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[*] Correct to two decimal places.

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