Course grade and self-efficacy before and during the pandemic for female and male introductory physics students who typically worked alone or in groups

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Meaningful collaboration with peers inside and outside the classroom can be an invaluable tool for helping students learn physics. We examined the characteristics of women and men who typically worked alone versus those who worked with peers in their algebra-based introductory physics course. We compared periods before the COVID-19 pandemic, when classes were conducted traditionally, and during the pandemic, when classes were conducted via Zoom. We find that on average, those who typically worked with peers had higher grades and reported greater peer influence on their physics self-efficacy during the COVID pandemic than before it. We discuss these findings in relation to students' prior academic preparation, physics grade and self-efficacy as well as student perception of the effectiveness of working with peers on their physics self-efficacy.

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I. INTRODUCTION AND FRAMEWORK

When students collaborate with peers to solve physics problems, the benefits can often be significant [1-5]. The distributed cognition framework explains the benefits of collaboration and support from peers based upon an increase in cognitive resources since the working memory of each individual is limited [6, 7]. Additionally, when collaborative work ensures positive interdependence [8] and individual accountability [9, 10], students at all levels of prior knowledge can benefit. This includes high achieving students as discussion with peers is a powerful way to reinforce one's own understanding and clarify ideas [2, 4]. Since improving students' physics problem solving skills is important [11-16], collaboration with peers can play a major role in enhancing students' problem solving skills, academic performance, and boosting their self-efficacy [17-21].

Research studies show that while some students may experience social anxiety, others may have preference for wanting to work alone or maybe compelled to work alone due to other constraints [17]. Gender dynamics can also influence students' preferences for collaborative work. Due to stereotypes and biases, women might feel less confident while working in groups [22, 23]. Conversely, in mixed gender groups, men might dominate group interactions, potentially discouraging women's participation. Also, if class time does not emphasize the value of working with others and model effective approaches to working with peers [24], students may not realize the importance of collaboration outside of class or know how to work effectively with peers. In-class group work that is engaging and productive can inspire students to continue collaborating outside of class. Creating an inclusive learning environment [25, 26], providing encouragement, and sharing data with students about the effectiveness of working with peers both inside and outside the class can increase their willingness and prioritization to collaborate with peers [27-33].

The COVID-19 pandemic brought new changes in the teaching and learning practices with institutions shifting to remote classes. During the COVID period, students attended Zoom classes, and instructors were encouraged not to give high-stakes exams [34, 35]. They were further advised to distribute the course grade with low-stakes assessments spread across the 14-weeks semester. Hence, it is important to consider the impact of new teaching and assessment methods during COVID on peer collaboration, students' academic achievements and their peer influence on self-efficacy (PISE).

We conducted a study to investigate these issues and compared outcomes before and during COVID at the end of an algebra-based introductory physics course. We also investigated student grade and PISE as outcomes by controlling students' gender, their self-efficacy (SE) and prior preparation. We analyzed the data for women and men separately to understand if the likelihood of typically working alone or in groups differed by gender. We note that the interactions with peers related to the physics course include students' experiences both inside and outside the class. For example, students may work together on their homework after class. Since there was no explicit effort by the course instructors in this study to encourage group work inside or outside of the classroom, this study provides baseline data on what the landscape looks like regarding students typically working alone (TWA) or typically working in groups (TWG) throughout an introductory physics course at a large research university. It can serve as a resource for instructors who encourage and model peer interaction by incorporating evidence-based collaborative practices in their classes.

II. RESEARCH QUESTIONS

We investigated the following research questions in our study:

1. Are there any differences in average grade, PISE and SE between students who TWA and those who TWG before and during the COVID pandemic?
2. What percentages of women and men typically worked alone or in groups and what motivates them to do so?
3. Do any patterns observed in RQ1 differ for women and men?
4. Do gender and TWA/TWG predict PISE and grade when controlling for self-efficacy and prior preparation before and during COVID?

III. METHODOLOGY

The study took place at a large public research university in the US. We administered a survey asking students whether they typically worked with peers or alone throughout the physics course as well as questions about psychological constructs such as SE and PISE (see Table I) to the students in the algebra-based introductory Physics 1 course in three consecutive fall semesters. The survey was given during the last week of their mandatory teaching assistant led recitations. For analysis, we included students who completed the survey and passed an attention check (a question that requested the students select "C"). Most of the students in the sample were juniors and seniors who were mainly biological science majors and/or those interested in health-related professions. 797 students took the survey before COVID and 343 took it during the COVID fall semester when the classes were on Zoom.

The PISE items measured whether students thought that working with their peers was beneficial to their confidence to do physics [4] whereas the self-efficacy (SE) items measured their confidence to succeed in a physics course [36, 37]. These items were constructed from other surveys and were previously validated [37-40]. We also performed confirmatory factor analysis (CFA) [41] to confirm survey validity for PISE and SE items. The Comparative Fit Index

(CFI) and Tucker Lewis Index (TLI) were ≥ 0.95, the Root Mean Square Error of Approximation (RMSEA) was ≤ 0.08 and the Standardized Root Mean Residual (SRMR) was ≤ 0.06. Both PISE and SE items were on a four-point Likert scale (1 – Strongly Disagree, 2 – Disagree, 3- Agree, 4 – Strongly Agree).

Table I: The peer influence on self-efficacy (PISE) and self-efficacy (SE) items on the survey.

Item No.	My experiences and interactions with other students in this class:
PISE 1	Made me feel more relaxed about learning physics
PISE 2	Increased my confidence in my ability to do physics
PISE 3	Increased my confidence that I can succeed in physics
PISE 4	Increased my confidence in my ability to handle different physics problems
SE 1	I am able to help my classmates with physics in the laboratory or in recitation.
SE 2	I understand concepts I have studied in physics.
SE 3	If I study, I will do well on a physics test.
SE 4	If I encounter a setback in a physics exam, I can overcome it.

The average value of the 4 items related to PISE (see Table I) was calculated for each student, and it was z-scored, $Z = (\mathrm{X} - \bar{X})/\sigma_X$, meaning that observations were converted to measure the number of standard deviations (SD, σ_X) they were from the mean of all students ($\bar{X}$) and rescaled to a range from 0-1 using $(\mathrm{Z} - \mathrm{Z}_{min})/(\mathrm{Z}_{max} - \mathrm{Z}_{min})$ [41]. The z-scoring was performed separately for non-COVID and COVID semesters. This process was repeated for grades and self-efficacy items.

To determine the gender differences and differences in grade, PISE, and self-efficacy for students who TWA and students who TWG, we calculated Cohen's *d* between groups. Cohen's $d = (\bar{\mathrm{X}}_1 - \bar{\mathrm{X}}_2)/\mathrm{S}_{\mathrm{pooled}}$, where $\bar{\mathrm{X}}_1$ and $\bar{\mathrm{X}}_2$ refer to the sample means of these two groups and $\mathrm{S}_{\mathrm{pooled}}$, the pooled standard deviation [41], is a measure of effect size. We used the following standards: small, $d \sim 0.2$; medium, $d \sim 0.5$; and large $d \sim 0.8$. We note that gender is not a binary construct, but the data collected by the university only included binary options of women and men.

We used multiple regression analysis to explore the predictive relationship between PISE and grade with other variables such as gender, grade, high school (HS) GPA, SAT (Scholastic Assessment Test) Math, and self-efficacy. For each regression model, we report the standardized β coefficients and adjusted R-squared. Standardized coefficients were used because they are in units of standard deviation and allow for comparison of effects.

We also inquired about the reasons why students preferred to work alone or in groups in the survey using an open-ended question which asked students to summarize why they primarily worked alone, or in groups. We note that these reasonings were only collected in the semesters after the COVID pandemic.

IV. RESULTS AND DISCUSSION

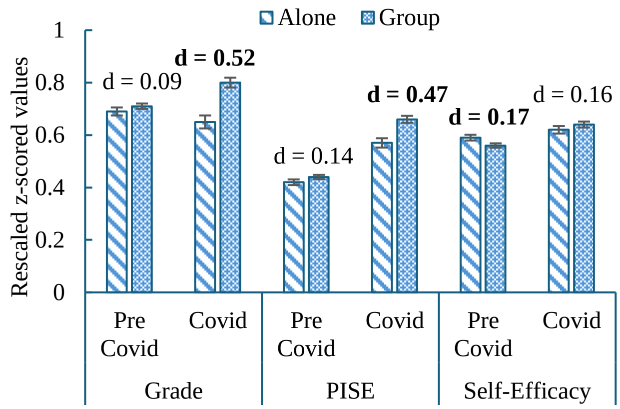

Fig. 1: Grade, PISE and SE of students who typically worked alone and in groups with Cohen's *d*.

Regarding RQ1, we examined the disparities in grades, peer influence on self-efficacy (PISE), and self-efficacy between students who TWA and those who TWG, without considering their gender. The analysis revealed that there was no statistically significant difference in grades and PISE between these two groups before COVID (see Fig. 1 in which significant values are bolded). However, this difference became statistically significant during COVID with students who TWG having higher average grades and PISE. The effect sizes for these differences were in the medium range, 0.52 for grades and 0.47 for PISE. Regarding self-efficacy, there was a statistically significant difference between students who TWA and those who TWG before COVID with higher self-efficacy for those who typically worked alone (see Fig.1), but this difference was not statistically significant during the pandemic. Also, self-efficacy increased for students who worked alone and those who worked in groups during the COVID period compared to before the pandemic.

Regarding RQ2, the common reasons students cited for choosing to work either alone or in groups were to gain a deeper understanding of physics and improve their interpretation of physical laws. These reasonings were collected from the students after the COVID pandemic when they were back to traditional classroom settings. Table II shows that most women and men TWG both before and during COVID. Reasonings suggest that students who TWG find it beneficial for clarifying concepts through discussion and debate. They thought that collaboration and exchange of perspectives led to deeper understanding and better solutions. Students also noted that group work provides social support and motivation, making it easier to stay engaged and motivated to solve problems.

Table II also shows that a higher percentage of men (42%) typically worked alone compared to women (31%) before the pandemic. It increased during COVID with 48% men and 37% women typically working alone (see Table II).

Table II: Number of women and men who worked alone and in groups before and during COVID.

	Before COVID		During COVID	
	Women	Men	Women	Men
Alone	164 (31%)	110 (42%)	77 (37%)	64 (48%)
Group	368 (69%)	155 (58%)	132 (63%)	70 (52%)
χ^2	8.95 (p = 0.003)		4.02 (p = 0.045)	

Both women and men who TWA mentioned the ability to focus better on tasks when working alone. Additionally, they mentioned that they could delve deeper into topics they found challenging and make mistakes without fear of judgment from peers when working alone. Efficiency and the ability to work at their own pace were also mentioned by both women and men as key factors influencing their decision to work alone. We also observed some gender differences in the reasons students gave for typically working alone based on the survey results. Some of the most prominent reasons from women indicated feeling intimidated by others' knowledge/showing off, which can be related to social dynamics. Some women also explicitly mentioned experiencing discouragement from men leading them to work alone. In contrast, men who typically worked alone stated a preference for solving problems independently or feeling more productive when working alone.

Regarding RQ3, our findings suggest that grade is significantly higher for men who worked in groups compared to women, $d \sim 0.37$ before COVID, but this difference became statistically insignificant during COVID (see Fig. 2). The gender difference in PISE is statistically significant before COVID but it is not during COVID (see Fig. 3). In contrast, gender difference is always statistically significant for self-efficacy, and the gender gap in self-efficacy is higher for students who worked alone compared to those who worked in groups (see Fig. 4).

Regarding grades, there was no statistically significant difference between students who TWA and those who TWG before COVID. But this difference became statistically significant during the COVID pandemic for both women and men. Students who TWG had a higher grade than those who worked alone with a medium effect size of $d \sim 0.50$. This indicates that students derived greater benefits from collaborative group work during the pandemic compared to traditional in-person courses.

Also, women who TWA had a significantly lower PISE than those who TWG both before ($d \sim 0.22$) and during COVID ($d \sim 0.49$). We find similar results for men; however, this difference was statistically significant only during the COVID pandemic ($d \sim 0.53$). This result makes sense as individuals who perceive benefits in collaborating with others are likely to TWG and have higher PISE.

We note that there was no statistically significant difference in self-efficacy for men who TWA compared to those who TWG. This difference was statistically significant for women during COVID with higher self-efficacy for those who TWG ($d \sim 0.37$). This correlation between the group

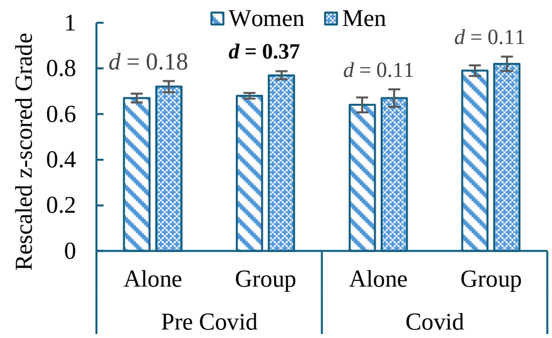

Fig. 2: Grades of the students who TWA and TWG divided by gender along with standard error.

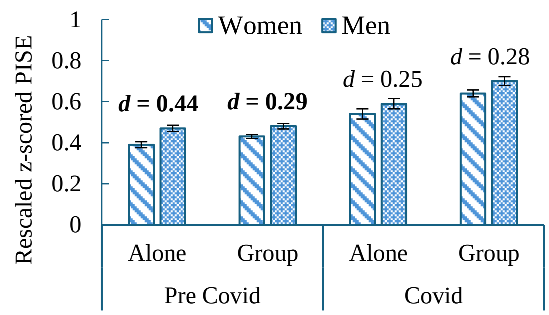

Fig. 3: PISE of the students who TWA and TWG divided by gender along with standard error.

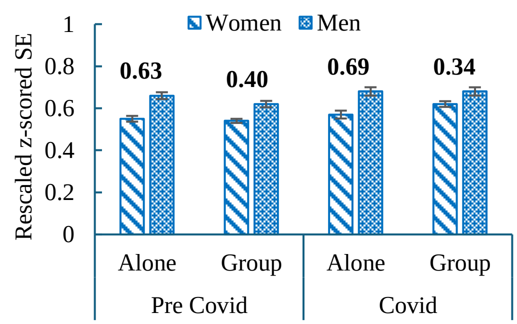

Fig. 4: Self-Efficacy (SE) of the students who TWA and TWG divided by gender along with standard error.

work and women's SE during the pandemic and reduction in gender gap is interesting.

Regarding RQ4, Tables III and IV show the results of some useful regression models predicting grade and PISE, respectively. The independent variables (predictors) used for regressions are in the first column and any blank spaces indicate that the predictor in the corresponding row is not used in that model. The strength of each predictor is given by the standardized coefficients (β) controlling for all other variables. For each change of a standard deviation shown in a predictor variable, the model predicts a change of β standard deviation in the outcome variable controlling for all other predictor variables.

Table III: Standardized β coefficients of regression models predicting grades. [Gender: F (0) = women and M(1) = men. Group:

Students who typically worked alone (TWA) = 0 and students who typically worked in groups (TWG) = 1.] Significant predictors are bold. * = p < 0.05, ** = p < 0.01, and *** = p < 0.001 [41].

Before COVID (Grade as the outcome variable)				
Predictors	Model 1	Model 2	Model 3	Model 4
Gender	**0.14*** **	0.05	**0.11*** **	**0.08** **
Alone/Group	0.06	**0.08* **	**0.07* **	**0.09** **
PISE		0.02	**0.15*** **	0.03
HS GPA			**0.29*** **	**0.27*** **
SAT Math			**0.37*** **	**0.33*** **
SE		**0.39*** **		**0.27*** **
Adj. R^2	0.02	0.17	0.33	0.37
COVID (Grade as the outcome variable)				
Predictors	Model 1	Model 2	Model 3	Model 4
Gender	0.05	-0.01	0.04	0.03
Alone/Group	**0.26*** **	**0.22*** **	**0.19*** **	**0.20*** **
PISE		0.03	**0.09* **	0.05
HS GPA			**0.23*** **	**0.22*** **
SAT Math			**0.34*** **	**0.33*** **
SE		**0.30*** **		0.10
Adj. R^2	0.06	0.12	0.28	0.29

Regression models predicting grades (Table III) before the COVID pandemic show that gender is a statistically significant predictor (except Model 2). Alone/Group is not a statistically significant predictor, when only gender is controlled for, but it becomes significant when other variables such as PISE, SE, HS GPA and SAT Math are included in the model. PISE is significant when prior high school preparation is included. However, including SE renders the PISE statistically non-significant suggesting that PISE is correlated with self-efficacy as observed in Model 3. In contrast, gender is not a statistically significant predictor of grade during the COVID pandemic (see Table III). Alone/Group is a statistically significant predictor in all four models. This indicates that students who worked in groups had higher grades, irrespective of their gender during the COVID pandemic.

Table IV: Standardized β coefficients of regression models predicting PISE. Significant predictors are bold. (* = p < 0.05, ** = p < 0.01, and *** = p < 0.001) [41].

Before COVID (PISE as the outcome variable)				
Predictors	Model 1	Model 2	Model 3	Model 4
Gender	**0.16*** **	**0.13*** **		0.04
Alone/Group	**0.08* **	**0.07* **		**0.11*** **
Grade		**0.22*** **		0.02
SE			**0.49*** **	**0.52*** **
Adj. R^2	0.03	0.07	0.24	0.29
COVID (PISE as the outcome variable)				
Predictors	Model 1	Model 2	Model 3	Model 4
Gender	**0.13* **	**0.12* **		0.02
Alone/Group	**0.24*** **	**0.21*** **		**0.19*** **
Grade		**0.14** **		0.02
SE			**0.49*** **	**0.47*** **
Adj. R^2	0.06	0.08	0.24	0.27

In Models 1 and 2 (Table IV), men exhibited a higher PISE than women when controlling for Alone/Group (Model 1) or both Alone/Group and grade (Model 2). Both models explain a small amount of variance as adjusted R^2 does not exceed 0.08. This suggests that additional factors are needed to explain this difference. Model 3 in Table IV suggests that self-efficacy is a strong predictor of PISE, explaining 24% of the variance on its own. Also, when self-efficacy is included in Model 4, gender and grade become non-significant, indicating that SE may account for some differences observed in PISE related to gender and grade.

V. CONCLUSION AND LIMITATIONS

Since our study provides baseline data when there was no explicit effort to have students engage in group work inside or outside of the classroom, these findings could serve as a reference for others who investigate the effectiveness of peer collaboration in their courses. Although there was no incentive provided to students for group work in our research, we observed that students who TWG, on average, earned higher grades compared to those who TWA during the pandemic. The PISE was higher for both women and men during COVID regardless of whether they TWA or TWG. Additionally, self-efficacy was higher among women who TWG during COVID compared to those who worked alone. Moreover, the gender difference in grades and self-efficacy was smaller for students who TWG during the pandemic than before it which could be attributed to a higher grade and SE among women who TWG during the pandemic.

During the pandemic, many students found themselves isolated due to lockdowns and social distancing measures. Gaining a deeper understanding of student behavior and its impact on learning through in-depth interviews can provide valuable insights into the benefits of peer collaboration in both online and traditional classroom settings. Conducting one-on-one interviews with students can help explore how the social interaction and opportunities for peer collaboration were perceived as valuable (or not) when students interacted with each other on Zoom during the pandemic or in in-person classes. One important aspect to investigate in these interviews will be the extent to which the Zoom classes and peer interactions during the pandemic provided an environment that reduced the stereotype threat that many women experience in traditional in-person physics classes [42, 43]. It is possible that the physical separation and the option to turn off their video in Zoom classes may have enabled some women to focus better on the task at hand in collaborative work without worrying about being judged by others. If this hypothesis is true, it can improve their engagement in collaborative work and create a more equitable and inclusive space to benefit from peer interactions. Understanding these types of gender dynamics can provide valuable insights into how different settings impact women and men's motivation and engagement in collaborative work. Thus, this information from interviews can also help instructors design more effective collaborative learning environments to enhance all students' learning.

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