Does transitioning to online classes mid-semester affect conceptual understanding?

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Abstract. The Force Concept Inventory (FCI) can be used as an assessment tool to measure the gains in a cohort of students. In this study it was given to first year mechanics students (\(N = 256\) students) pre- and post-mechanics lectures, for students at the University of Johannesburg. From these results we examine the effect of switching mid-semester from traditional classes to online classes, as imposed by the COVID-19 lockdown in South Africa. Overall gains and student perspectives indicate no appreciable difference of gain, when bench-marked against previous studies using this assessment tool. When compared with 2019 grades, the 2020 semester grades do not appear to be greatly affected. Furthermore, initial statistical analyses also indicate a gender difference in mean gains in favour of females at the 95% significance level (for paired data, \(N = 48\)). A survey given to students also appeared to indicate that most students were aware of their conceptual performance in physics, and the main constraint to their studies was due to difficulties associated with being online. As such, the change in pedagogy and the stresses of lockdown were found to not be suggestive of a depreciation of FCI gains and grades.

Keywords: Physics Education; Large Cohort Courses; Online Teaching; Force Concept Inventory; FCI.
1. Introduction

Many studies through the years have advocated for various changes to teaching pedagogy away from the so-called traditional lecturing pedagogy, such as flipped classrooms, and peer-assessment [1, 2, 3, 4, 5, 6], to name but a few. Many of these studies have used assessment tools, such as the Force Concept Inventory (FCI) [7, 8, 9], to assess the efficacy of these changes, where such drastic changes have been regarded over many years of studies. As such, with the FCI now considered as a *de facto* standard for assessing the conceptual basis of Newtonian mechanics, and a gain when comparing these test results both before and after an introductory mechanics course of approximately 25% [10, 11] as a benchmark for standard performance in a course’s approach, we can now ask the question of what happens when the pedagogical approach is forcibly changed during the semester, with no forewarning to either the lecturers or the students.

Whilst this study has been conducted for only one year worth of data, where as mentioned above, usual analyses of such changes in pedagogy are conducted over years, during the 2020 lockdown experienced in South Africa as a result of the COVID-19 pandemic, we were presented with a unique opportunity to test the resilience of this assessment tool, as well as the effects such sudden changes could have on the usual gains in a first year mechanics course. As such, our study was conducted with a very diverse group of first year students enrolled in the University of Johannesburg (UJ), Faculty of Engineering and the Built Environment (FEBE), whose demographics (average 2015 - 2019) range as follows: African 92.8%; White 3.8%; Indian 2.3%; Coloured 1.1% [12]. Yet for such a diverse background, the gains appear to have remained comparable to the bench-marked studies of the last three decades.

Given the necessary switch to online platforms, such as Blackboard [13], we are also able to study the engagement of students within this online learning environment (through their attendance and marks on continuous assessments). This also includes the time taken to complete various assessment tasks.

It may be considered somewhat surprising that even with the above-mentioned change in pedagogy, we found no appreciable change in the FCI gain across this course (see later comments). In seeking to break this down we shall look at a number of factors, including the previously studied Gender Gap [14, 15, 16, 17, 18, 19, 20], where there has been a resulting gender difference in favour of males in the student performance on standardised assessments, such as the FCI in previous studies. However, our results indicate this does not seem to be the case here. Another aspect at play here could be the increased peer scaffolding (along the lines of Mazur’s peer evaluation [21]) as there had been an increased reliance on discussion groups with peers, due to the COVID lockdown. This persisted into the second semester, as was highlighted by the perspectives of the mechanics lecturers, where a range of discussion boards, interactive tutorials, and WhatsApp groups were still used. As presented in Table 1, it can be seen that the scores for the average semester 2 mark for both 2019 and 2020, which includes a combination of coursework, practicals and exams, were not appreciably different. The
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only noticeable difference was in the number of students who passed after the November exam, or the course throughput, where explained in the table caption, in 2020 a slightly lower semester mark was used to gain entrance to the final exam.

Given these motivations our paper shall be presented as follows: In section 2 we shall detail the methodology of our study, followed by the analysis tools and techniques used in this study in section 3, along with supporting appendices, and finally we shall conclude in section 4.

|                                | 2019 | 2020 |
|--------------------------------|------|------|
| no. of enrolled students (excluding cancellations) | 349  | 404  |
| average semester mark (%), all students         | 54   | 63   |
| average semester mark (%), only students who qualified for exam | 58   | 66   |
| % students qualified for written exam           | 75   | 93   |
| average exam mark (%)                          | 48   | 50   |
| average course mark (%), all students           | 45   | 55   |
| average course mark (%), only students who qualified for exam | 53   | 58   |
| course throughput (%)                          | 49   | 67.5 |

**Table 1:** Comparison of the 2019 and 2020 marks for engineering physics 1 in the second semester. Note that: 1) the course throughput is calculated after the main exam only, excluding the results of the supplementary exams; 2) In 2020 the entrance requirement for the exam was lowered to 30% for the theory part of the course (instead of the usual 40% in 2019 and previous years) in light of the COVID-19 pandemic.

2. Methodology

The subjects for our testing were the 2020 first year cohort of engineering students at the University of Johannesburg. The class consisted of approximately 400 students. The course was initially taught as a traditional lecture based course, with a weekly online assessment, fortnightly tutorials and fortnightly practicals (these being done in person in groups of approximately 30 students with graduate students acting as tutors and demonstrators of the practicals). The academic year had begun in early February of 2020, where the pre-mechanics course FCI test was conducted in late February on \( N = 256 \) students.†

The end result of the FCI is defined by the normalised gain \( G \) [10]:

\[
G = \frac{\langle \% S_f \rangle - \langle \% S_i \rangle}{100 - \langle \% S_i \rangle},
\]

† From a cohort of 400 students 256 students sat the FCI, where for pre- and post-test cases there were 144 and 166 students, respectively. After removing several redundant attempts, there were 256 data subjects in total. Those who took both tests (paired) were 48 in total.
where \( \%S_f \) and \( \%S_i \) are the final and initial scores respectively. We found that for this cohort (for paired data) \( N = 48 \) the average gain was at 24\%. We will comment further on these results in Sec. 3.1.

First we should note that South Africa was placed in a hard lockdown in mid-March 2020, and teaching was switched within the period of a few weeks to a purely online format. Lectures were replaced with recorded video content, and online platforms for engagement with students were employed (such as consultations using BlackBoard Collaborate Ultra, and WhatsApp discussion groups). As the easing of the lockdown occurred towards the end of the mechanics course, a post-FCI test was possible to administer to a smaller voluntary group of students, of which \( N = 48 \) had done the pre-test.

Note that online teaching in a similar manner continued into the second semester (where the physics syllabus covers electromagnetism and optics), where one of the authors was a lecturer for this course. As such, continued performance could also be assessed for these students over the entirety of their first year physics studies, as well as conducting an online survey with these students for their perspectives of the course and their feelings of success or failure. It should also be noted that the authors of this study are actively taking part in the running, teaching and tutoring of the students. Hence, we can also provide the perspectives of the lecturers of this course, and those of the tutors involved, including the stresses of changing the teaching format mid-semester.

The methodology employed to unpack this collected data relied primarily on standard statistical parameters, including the mean, standard deviation, percent differences, \( p \)-values for the \( t \)-test difference of means, and correlations through R [22, 23] and a spreadsheet.‡

Using our data from this cohort in Sec. 3 we shall investigate:

(i) student performance from pre-test to post-test, including an analysis of their performance in the pre- and post-tests via a question breakdown, see Sec. 3.1,
(ii) the existence of a polarisation effect in 6 particular questions [25], see Sec. 3.2,
(iii) a possible gender difference in the FCI for paired data, see Sec. 3.3,
(iv) and a discussion of student and staff surveys, where as is usual we used a Likert scale [26], see Sec. 3.4.

3. Results & Analyses

3.1. Question Break Down, Means and Gains

In this section we first present some analyses of the distribution of the scores for students in the pre- and post-tests (\( N = 256 \)), starting in the left panel of Fig. 1 (where the right

‡ Interested readers who wish to familiarise themselves with the basics of statistical analysis, including the \( t \)-test, correlation, ANOVA, and measures of variation (e.g. standard deviation and standard error of the mean), among others, may want to consult Refs. [22, 24].
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Figure 1: A frequency histogram for the pre- and post-test data in total (\(N = 256\)) and for the paired data (\(N = 48\)).

|                  | Mean | SD  | Min. | Max. |
|------------------|------|-----|------|------|
| pre-test ALL     | 34.3 | 15.2| 3    | 80   |
| pre-test PAIRED  | 34.7 | 17.2| 3    | 80   |
| post-test ALL    | 44.1 | 22.8| 0    | 100  |
| post-test PAIRED | 50.8 | 22.4| 10   | 100  |

Table 2: Mean, standard deviation (SD), minimum and maximum % marks as displayed in Fig. 1. The paired data consisted of a subset (\(N = 48\)) of the \(N = 256\) who sat either the pre- or post test.

The difference in distributions (pre- compared to post-test) have well defined shifts indicating a gain, particularly for the paired data. In Table 2 the results for the pre- and post-test scores can be seen. The gain of \(G = 0.24\) was calculated from the paired data and is the expected gain for a standard physics course [10]. The difference in mean scores was checked via the paired samples \(t\)-test (\(N = 48\)) and was not due to random fluctuations at the 95% confidence level (\(p\)-value = 0.000002614, two-tailed), implying we found a statistically significant difference in the means (pre- and post-test).\(^\S\)

\(^\S\) The means for the pre- or post-tests groups used an independent samples \(t\)-test and was found to be not due to random fluctuations at the 95% confidence level; \(p\)-value = 0.00001182, two-tailed.
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This relationship between pre- and post-test scores can also be seen in Fig. 2, where the correlation in was found to be moderate and positive. It should be noted that the gain from the pre-test mean, as compared to the post-test mean, is not used to determine the gains [10], although we have performed a question by question breakdown. In terms of numbers, Pearson’s correlation coefficient, in Fig. 2, gives a moderate positive correlation of $r = 0.504$ with $p$-value $= 0.000261 < \alpha$ at the 95% significance level ($\alpha < 0.05$).

As student ideas may not be clearly understood, nor how much they have learnt according to their own perspectives or from interviews, we can identify them through analyses of question by question responses. Fig. 3 indicates the percentages of students who correctly answered each question in the pre- and post-tests, with the differences also shown (diagonal hatching/blue). A similar schematic is shown for the paired data (see bottom panel Fig. 3) for comparison. We note here the presence of negative gains for certain questions, which are indicative of poorer performance in the post-test. This “loss” is especially pronounced in Fig. 3, top panel, for questions 14, 20, 22, and 24; this also arises in the paired data of Fig. 3 for question 12, bottom panel; the negligible gains in question 21 for the former and questions 14 and 24 for the latter are also worth mentioning. The concepts assessed by these questions are standard topics such as projectile motion (questions 12 and 14), as well as kinematics and Newton’s second law (questions 20-24). However, these questions possibly exploit scenarios with which students are unlikely to have had personal experience with (i.e. objects fired from cannons and motion in deep space) and visual tools like ticker-tapes and displacement-time graphs. In doing so, they ensure that students respond based on intuition gained.
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Figure 3: Top: Correct answer analysis for all the students ($N = 256$) who wrote pre- and post-tests. Bottom: Correct answer analysis for all the paired students ($N = 48$) who wrote pre- and post-tests.

from their mechanics course rather than empirical evidence gathered from daily life.

Finally, poorer post-test performance in these more conceptual questions may demonstrate that students are not confident in their ability to apply their knowledge to unfamiliar scenarios. This may be a consequence of superficial learning or dependence on preconceived ideas rather than physics. The presence or development of misconceptions may also have come into play. Additionally, we note that these questions might indicate an issue with language ability, a concern shared by other studies conducted in regions where English is not the first language of most students [25, 27].
3.2. Polarising Questions

Another way to investigate individual questions has recently been performed in Refs. [20, 25, 28], where a breakdown of the type of response to individual questions can lead to a polarisation of a correct answer and one predominantly incorrect answer.\footnote{In Figs. 4 and 5 we can see the effect of the polarising questions: 5, 11, 13, 18, 29 and 30 in the FCI, e.g., see Ref. [25]. A similar pattern emerges for the cohort at UJ, where there clearly appears to be a subset where asides from the correct answer there is another polarising choice, and apart from Q18 in the “paired” data, Fig. 5, we find the same dominant incorrect (polarised) response [25].

It may be that certain misconceptions drive this polarisation. For example, consider question 5, where the dominant answer of C can be read from the pre-test data of Figs. 4 and 5. This answer claims that the motion of a ball is driven by gravity as well as “a force in the direction of motion”, which indicates the common misconception that motion requires an active force. The presence of a force in the direction of motion is favoured also in answers 11C, 13C, and 18D, as well as implied in 30E. Though there is a general decrease from pre- to post-test in the selection of these erroneous answers, the post-test data of Figs. 4 and 5 suggest that these misconceptions can be difficult to alleviate, as we have found at UJ.

Such observations connect well to the work of Bani-Salameh [30] and others; we shall interrogate these ideas in greater depth in a future work, see Sec. 4. It can certainly be inferred that there are subsets of incorrect answers where misconceptions in students’ understanding consistently leads to the same kind of wrong answer [25].

| Group     | Female | Male | Difference |
|-----------|--------|------|------------|
| n = 16    | n = 32 |
| Pre-test(%) | Mean (SD) | Mean (SD) | (Male-Female) |
|           | 31.0 (12.3) | 37.0 (19.4) | 6.0         |
| Post-test(%) | 56.9 (25.2) | 47.6 (20.5) | -9.3        |
| Gain(%)   | 38.0   | 17.3  | -20.7      |

\textbf{Table 3:} Paired FCI results (in percent) for female and male participants (\(N = 48\)).

3.3. Possible Gender Gains

In this section we now analyse the differences between the male and female participants who sat for both pre- and post-tests (paired). In Table 3 the means for female and male participants are presented and it clearly appears that female participants have performed better in the FCI as compared to male participants. Interestingly, and it has

\footnote{See Refs. [29, 27, 30, 31] for a discussion of other ways to analyse and interpret individual question responses in the FCI.}
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![Figure 4: Distribution of student answers for Questions 5, 11, 13, 18, 29 and 30, pre-(red) and post-(blue), for all $N = 256$ students. NA stands for “no answer”, while the five options are labelled from A to E.](image)

been found by Alinea & Naylor [20], the table shows that although male participants did better in the pre-test, female participants had a higher average in the post-test.

To further try and verify these results, where due to the average number of participants in each group being 24, we have in Appendix A performed multiple statistical tests to confirm if this difference in means is statistically significant. From this we have found that at the 95% significance level we can neglect the null hypothesis. We emphasize that besides parametric tests for normal distributions we have also performed a non-parametric Wilcoxon test that led to a statistical difference in the medians, see App. A.

In comparison to Fig. 2, in Fig. 6 the correlation for female and male groups was found to be mild and positive with: $r_F = 0.417$; $p$-value = 0.05418 and $r_M = 0.662$; $p$-value = 0.00001816, respectively. Clearly, there is a more reliable correlation for the male cohort with $p$-value < 0.05. Finally, this can be compared to the combined correlation (independent of gender, $N = 48$) where $r = 0.504$; $p$-value= 0.02757 in Fig. 2.

The reason for the apparently higher gain for the female part of the cohort might be due to, as found by Sadler and Tai [32] (also see Adams et al [33]), professor-to-gender matching to student gender was second only to the quality of high-school physics course in predicting students’ performance in college physics. It may be worth mentioning that at UJ, during the 2020 academic year, a female instructor was the senior academic for the mechanics course. As we discuss in Sec. 4, we will leave these preliminary results...
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Figure 5: Paired distribution of student answers for questions 5, 11, 13, 18, 29 and 30, pre-(red) and post-(blue), tests for the paired group ($N = 48$). The same conventions are used as in Fig. 4.

Figure 6: Correlations for combined scores in terms of gender.

for a follow-up work.
3.4. Staff & Student Surveys

In this section we briefly remark on student and staff surveys conducted at UJ in 2020 after the sitting of the FCI post-test. In this survey we used a Likert scale [26] for most of the data collection. From Adams et al. [33] - interviews revealed that the use of a five-point scale in the survey - as opposed to a three-point scale - was important. Students expressed that agree vs strongly agree (and disagree vs strongly disagree) was an important distinction and that without the two levels of agree and disagree they would have chosen neutral more often.

One month after the FCI post-test was administered, students were asked to complete a feedback form detailing their experience with the FCI assessment tool. This survey was primarily designed to gauge student perspectives compared with the FCI test mark obtained (student numbers served as the only identifier to preserve anonymity). As the survey was not compulsory (and this was during a hard lockdown) a rather small sample (22) of the 256 students opted to take the survey. Of these student respondents, only 8 had taken either the pre- or post-test, while the other 14 had written both. Already a pattern could be seen in terms of students that sat both tests, “paired”, compared with those who sat only the pre- or post-test.

If we look at the average mark obtained by the students who sat both tests, which was 10.80 for the pre-test and 12.57 for the post-test (out of 30), then when asked to rate their performance, most chose 3 ($\bar{x} = 2.67$) and 2 ($\bar{x} = 2.14$) on the Likert scale for the pre- and post-tests, respectively. Only one response exceeded 3: a student who had received 40% for the pre-test ranked their performance as 4. These results suggest that, for the most part, students are aware of their shortfalls and do not overestimate their ability.

Three survey questions directly inquired about the students’ experience regarding the shift to online learning. The first, asking if students felt they engaged with lecturers/tutors/classmates more through digital platforms than through standard classes, was met with a mixed response: most selected 3 ($\bar{x} = 2.91$), but of these, $\sim$ 18% chose “strongly agree” while $\sim$ 23% chose “strongly disagree”. Similarly, $\sim$ 18% claimed they “strongly agreed” that their performance was better thanks to online learning, although the average response was “disagree”. However, the final such question offered the most clarity: the average response to whether working from home challenged academic performance was 3.59; most answered “agree”, while $\sim$ 18% selected “strongly agree”. Given the South African context in general, and the UJ context specifically (where typically one third of the enrolled students are from Quintiles 1 and 2 schools][, see page 76 in Ref. [35], indicating a diffuse level of poverty), and that data is among the most expensive in the world [36], the difficulties of online learning can be especially pronounced.

∥ Public schools in South Africa are classified in so-called Quintiles, from 1 to 5. Quintile 1 schools include the poorest 20% schools, while Quintile 2 schools are the next poorest 20% of schools, and so on. Government funding is dispensed to public schools according to their Quintile classification, with the aim of redressing poverty and inequality in education, see Ref. [34].
4. Concluding remarks

In this article we have used the Force Concept Inventory (FCI) to look at the conceptual understanding of a large cohort of physics/engineering students at the University of Johannesburg (UJ) during the 2020 academic year. Mid-semester UJ went into lockdown and students then switched from a traditional lecture format to online platforms, yet this led to the very informative scenario where we have found no overall drop in gains ($G = 0.24$). This is reminiscent of what happened with regards to the Christchurch Earthquakes (2010-2011) which led to the closure of various high schools, where although a minority had negatives impacts there were many positives [37]. This was further established through the comparison of 2019 and 2020 semester marks at UJ (see Table 1) where we found no appreciable drop in marks.

In Sec. 3.2 we looked at a subset of questions where a polarisation of choices occurred, in that either the correct answer or one main incorrect answer dominated the post-test responses [25]. We found similar patterns for the students at UJ, which followed a very similar pattern to the data found in Refs. [25, 20, 28]. The importance of these questions relates to the fact that they ask the student to be able to understand certain particular concepts in physics, such as circular motion and motion requiring a force.

In Sec. 3.3 we looked at a possible out-performance of female students on the overall gain in the FCI. As was also found by Alinea & Naylor [20], although the male group started with a higher average pre-test score, their gain was less. As mentioned earlier, the main course lecturer was female, which may lead to professor gender matching in this cohort [32]. Although we rigorously checked that the difference in means was statistically significant (at the 95% confidence level, see App. A) we will report on a larger cohort inclusive of 2021 in a forthcoming work.

The article has raised some questions, such as why the general performance for the group of paired students was higher than those who took either of the pre- or post-tests. This is often due to the fact that students who are diligent are more likely to take both pre- and post-tests, and this can be seen from the fact that this group of students was also more likely to take the survey as well. Usually, overall gains are taken only from paired data, which is then used to compare to other cohorts and institutions. However, the question of using “unpaired” pre- and/or post-test data sets in some form has not really been investigated in the literature (see however, Ref. [27]) and we intend to comment more on this issue in future work.

As for other possible directions to investigate, besides extending the FCI to further years, which also appears to be disrupted by more COVID lock-downs, we intend to look at matriculation results in order to establish correlations between the FCI and high school exit grades in physics, maths and English scores. In the case of UJ, the first language of the students enrolled in the UJ FEBE (average 2015-2019): English 14.3%; Isixhosa 5.9%; African 1.5%; Other 78.3% [12]. This relates to comments by

** In terms of physics performance during COVID see Refs. [38, 39, 40].
Bani-Salameh [27], and also work performed by Alinea & Naylor [25], in relation to performance on the English version of the FCI, where English is not the student’s first language necessarily. It might also be interesting to look at correlations between the FCI and cognitive reflective tests [28].

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A. Statistical Analyses of Differences in Gender Means

In this appendix we look at the differences in gender means for paired data \((N = 48,\text{ comprising of 16 female participants and 32 male participants})\). We found that the mean of the gains for female participants \((\mu^F_G = 0.38)\) was greater than the mean for male participants \((\mu^M_G = 0.17)\). However, to clarify if the difference is purely a random fluctuation, we performed the following tests, using R [23], at the 95% significance level \((\alpha < 0.05)\):

(a) The \(t\)-test for independent samples (and unequal variances) had a \(p\)-value: \(0.02757 < \alpha\) for a single tail (directional difference \(\mu^F_G - \mu^M_G > 0\)).

(b) A two-way ANOVA with replication led to an \(F\)-statistic: \(4.5107\) and \(p\)-value: \(0.03909 < \alpha\).

(c) A linear regression analysis also led to an \(F\)-statistic: \(4.511\) and \(p\)-value: \(0.03909 < \alpha\).

(d) A non-parametric two-sample Wilcoxon test led to medians of 0.450296 and 0.1602564 for female participants and male participants, respectively, with a \(W\)-statistic of \(W = 341\) and \(p\)-value = \(0.03223 < \alpha\).

It may be worth mentioning that two-way ANOVA with replication was unbalanced, as the two group sizes were different (16 and 32, respectively). However, we were able to double-check the results obtained by converting gender to a dichotomous variable (Female= 1, Male= 0) and used a linear regression. At the 95% significance level (or \(\alpha < 0.05\)) we can reject the null-hypothesis whenever the \(p\)-value < \(0.05\).

In conjunction with the \(t\)-test, a two-way ANOVA and a linear regression analysis both agree at the 95% significance level, and suggest that there is a statistically significant difference between the means of female participants and male participants. This was further confirmed in item (d), where we performed a non-parametric test (using medians) and found the critical value to be \(p = 0.03223 < \alpha\). These findings indicate
Does transitioning to online classes mid-semester affect conceptual understanding? a **real** difference in gender (for this group) with female participants having better gains than male participants, even though male participants started with a higher average pre-test score.

References

[1] P. Heller, R. Keith, and S. Anderson, “Teaching problem solving through cooperative grouping. part 1: Group versus individual problem solving,” American Journal of Physics, vol. 60, no. 7, pp. 627–636, 1992.

[2] A. P. Fagen, C. H. Crouch, and E. Mazur, “Peer instruction: Results from a range of classrooms,” The Physics Teacher, vol. 40, no. 4, pp. 206–209, 2002.

[3] V. Cahyadi, “The effect of interactive engagement teaching on student understanding of introductory physics at the faculty of engineering, university of surabaya, indonesia,” Higher Education Research & Development, vol. 23, no. 4, pp. 455–464, 2004.

[4] M. K. Smith, W. B. Wood, W. K. Adams, C. Wieman, J. K. Knight, N. Guild, and T. T. Su, “Why peer discussion improves student performance on in-class concept questions,” Science, vol. 323, no. 5910, pp. 122–124, 2009.

[5] J. Watkins and E. Mazur, “Retaining students in science, technology, engineering, and mathematics (stem) majors,” J. Coll. Sci. Teach., vol. 42, p. 36–41, 2013.

[6] S. Freeman, S. L. Eddy, M. McDonough, M. K. Smith, N. Okoroafor, H. Jordt, and M. P. Wenderoth, “Active learning increases student performance in science, engineering, and mathematics,” Proceedings of the National Academy of Sciences, vol. 111, no. 23, pp. 8410–8415, 2014.

[7] H. I. A. and H. D., “The initial knowledge state of college physics students,” American Journal of Physics, vol. 53, p. 1043, 1985.

[8] D. Hestenes, M. Wells, and G. Swackhamer, “Force concept inventory,” The Physics Teacher, vol. 30, no. 3, pp. 141–158, 1992.

[9] H. D, “Who needs physics education research!?,” American Journal of Physics, vol. 66, p. 465, 1998.

[10] H. RR, “Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses,” American Journal of Physics, vol. 66, p. 64, 1998.

[11] V. P. Coletta and J. A. Phillips, “Interpreting fci scores: Normalized gain, preinstruction scores, and scientific reasoning ability,” American Journal of Physics, vol. 73, no. 12, pp. 1172–1182, 2005.

[12] U. FEBE, “University of johannesburg faculty of engineering and the built environment 2019 annual report,” 2020. https://www.uj.ac.za/faculties/febe/Pages/annual-report.aspx.

[13] Blackboard, “Blackboard collaborate,” 2016. http://www.blackboard.com/online-collaborative-learning/blackboard-collaborate.aspx.

[14] J. Docktor and K. Heller, “Gender differences in both force concept inventory and introductory physics performance,” AIP Conference Proceedings, vol. 1064, no. 1, pp. 15–18, 2008.

[15] H. M. Glasser and I. John P. Smith, “On the vague meaning of “gender” in education research: The problem, its sources, and recommendations for practice,” Educational Researcher, vol. 37, no. 6, pp. 343–350, 2008.

[16] A. Madsen, S. B. McKagan, and E. C. Sayre, “Gender gap on concept inventories in physics: What is consistent, what is inconsistent, and what factors influence the gap?,” Phys. Rev. ST Phys. Educ. Res., vol. 9, p. 020121, Nov 2013.

[17] S. Bates, R. Donnelly, C. Macphee, D. Sands, M. Birch, and N. Walet, “Gender differences in conceptual understanding of newtonian mechanics: A uk cross-institution comparison,” European Journal of Physics, vol. 34, no. 2, pp. 421–434, 2013.
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[18] V. Coletta, “Reducing the fci gender gap,” in Physics Education Research Conference 2013, PER Conference, (Portland, OR), pp. 101–104, July 17–18 2013.

[19] J. R. Shapiro and A. Williams, “The role of stereotype threats in undermining girls’ and women’s performance and interest in STEM fields,” Sex Roles, vol. 66, pp. 175–183, 2012.

[20] A. L. Alinea and W. Naylor, “Gender gap and polarisation of physics on global courses,” Physics Education, IAPT, vol. 33, 2017.

[21] E. Mazur, Peer Instruction: A User’s Manual. Series in Educational Innovation, Prentice Hall, 1997.

[22] M. J. Crawley, Statistics: An Introduction Using R (2nd ed.). Wiley, West Sussex UK, 2014.

[23] R Core Team, R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria, 2013.

[24] T. Urdan, Statistics in Plain English (3rd ed.). Routledge, 2010.

[25] A. L. Alinea and W. Naylor, “Polarization of physics on global courses,” Physics Education, vol. 50, pp. 210–217, 2015.

[26] R. Likert, “A method for measuring the sales influence of a radio program,” Journal of Applied Psychology, vol. 20, pp. 175–182, 1936.

[27] H. N. Bani-Salameh, “How persistent are the misconceptions about force and motion held by college students?,” Physics Education, vol. 52, p. 014003, dec 2016.

[28] A. L. Alinea, “Cognitive reflection test and the polarizing force-identification questions in the FCI,” European Journal of Physics, vol. 41, p. 065707, oct 2020.

[29] T. Martin-Blas, L. Seidel, and A. Serrano-Fernández, “Enhancing force concept inventory diagnostics to identify dominant misconceptions in first-year engineering physics,” European Journal of Engineering Education, vol. 35, no. 6, pp. 597–606, 2010.

[30] H. N. Bani-Salameh, “Using the method of dominant incorrect answers with the FCI test to diagnose misconceptions held by first year college students,” Physics Education, vol. 52, p. 015006, nov 2016.

[31] J.-i. Yasuda, N. Mae, M. M. Hull, and M.-a. Taniguchi, “Analyzing false positives of four questions in the force concept inventory,” Phys. Rev. Phys. Educ. Res., vol. 14, p. 010112, Mar 2018.

[32] P. M. Sadler and R. H. Tai, “Success in introductory college physics: The role of high school preparation,” Science Education, vol. 85, no. 2, pp. 111–136, 2001.

[33] K. Adams, S. Hean, P. Sturgis, and J. M. Clark, “Investigating the factors influencing professional identity of first-year health and social care students,” Learning in Health and Social Care, vol. 5, no. 2, pp. 55–68, 2006.

[34] H. van Dyk and C. White, “Theory and practice of the quintile ranking of schools in South Africa: A financial management perspective,” South African Journal of Education, vol. 39, p. 1820, 2019.

[35] UJ, “University of johannesburg 2018 stakeholder report,” 2018. https://www.uj.ac.za/about/Documents/UJ%20Stakeholder%20Report%202018%20FINAL%20(4).pdf.

[36] B. I. S. A. Edward-John Bottomley, “Sa has some of africa’s most expensive data, a new report says – but it is better for the richer,” May 05, 2020. https://www.businessinsider.co.za/how-sas-data-prices-compare-with-the-rest-of-the-world-2020-5.

[37] B. Beaglehole, C. Bell, C. Frampton, and S. Moor, “The impact of the canterbury earthquakes on successful school leaving for adolescents,” Australian and New Zealand Journal of Public Health, vol. 41, no. 1, pp. 70–73, 2017.

[38] J. D. White, “Teaching general physics in a COVID-19 environment: insights from taiwan,” Physics Education, vol. 55, p. 065027, oct 2020.

[39] P. Klein, I. Lana, M. N. Dahlkemper, K. Jeličić, M.-A. Geyer, S. Küchemann, and A. Susac, “Studying physics during the covid-19 pandemic: Student assessments of learning achievement, perceived effectiveness of online recitations, and online laboratories,” arXiv, 2020.

[40] M. F. J. Fox, A. Werth, J. R. Hoehn, and H. J. Lewandowski, “Teaching labs during a pandemic: Lessons from spring 2020 and an outlook for the future,” arXiv, 2020.