Assessing various factors influencing student education in statics

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Abstract: Engineering statics is one of the core courses typically offered to first year students and taught in most universities across the world that offer undergraduate degrees in engineering. This course utilizes concepts first learnt in high school Physics and Math and forms the basis for several other engineering courses such as Strength of Materials and Structural Analysis. A proper understanding of the concepts in statics is important for student learning to enable them to become accomplished engineers. Oklahoma State University (OSU) offers this course in Fall, Spring and Summer semesters as a common course for all branches of engineering. There are several 'features' pertaining to the course being offered at OSU that are worth mentioning. For instance, the course spans over sixteen weeks in fall and spring semesters, while the duration is reduced to eight weeks in summer. Also, the course is offered online and in-person in the summer semester, while in fall and spring the course is offered only in-person. For all three semesters, the course is taught by a different set of instructors, with a larger number (>200) of students registered in both the fall and spring semesters and a smaller number (<100) attending in summer. Although there are differences between the syllabus used in fall, spring and summer, evaluation of student performance for all three semesters is similarly based on exams, quizzes and assignments, with a common grading system. This paper assesses the student performance in statics over the past few years at OSU, across various semesters while considering the various 'features' of the course. Results indicate that the performance of students in fall and summer are generally better than in spring with a larger number of students obtaining 'A' or 'B'. In-person learning in the post covid times (after 2021) has resulted in improved student performance compared to covid times. Recent developments in the introduction of supplemental instruction (SI) leaders at OSU is an initiative that is expected to see further improvements. Future work focused on hands-on learning and guest lectures from industry, can greatly enhance student learning.

Keywords: Statics; Student performance; Engineering; Exams; Undergraduate degree

1. Introduction

Statics is a course that is taught to first year undergraduate students of most engineering disciplines at Oklahoma State University (OSU). In particular, this course has applications for students from architecture, architectural engineering, civil and mechanical engineering, since several courses such as structural analysis and strength of materials that are part of these disciplines utilize the principles of statics [1]. Therefore, a good knowledge of statics creates a solid foundation for the student, that is necessary to better understand other mechanics related subjects in their respective disciplines [2, 3, 4]. Due to the importance of this course, it is necessary to analyze student performance and determine methods for improvement. It has long been recognized that student performance can be greatly influenced by the method of instruction. For instance, Rutz et al [5]

has shown that web-based technology can enhance student learning of statics. Similarly, some studies have shown that concepts taught through demonstrations are better understood by students [6]. Students have also greatly benefited from hands-on learning as shown by Meijia et al [7] where the concept of truss analysis was explained by building miniature models.

At OSU, Statics has been taught for several years by various instructors, including some of the authors of this article. This course is typically taught in Fall, Spring and Summer semesters of each year. Classes in Fall and Spring semesters are 15 weeks in length, with one week break, while summer classes last for 8 weeks. Also, classes in Fall and Spring are three days a week, about one hour each day, while summer classes are four days a week for an hour and fifteen minutes each day. Furthermore, in Summer, students can choose to take the classes either online or in-person, while classes in fall and spring are only offered in-person. Although the syllabus taught in all three semesters and the grading system is similar, it is taught by a different set of instructors each semester, along with changes in assessment across the three semesters. Most of the results discussed in this study pertain to the post-Covid times (after 2021), with limited results from 2020 and 2021.

Results show that in general, there is a higher enrolment of students in fall when compared to spring [e.g. 335 students in fall 2022 and 186 students in spring 2022], although the percentage of top performers (students getting an 'A') is higher in fall (30% in 2022) than in spring (17% in 2022). Failure rates were also found to be higher in spring (21% in 2022) compared to fall (10% in 2022). A better performance in fall compared to spring may be attributed to students' improved performances in Math and Physics. Compared to Spring, the combined percentage of students getting 'A' or 'B' is higher in summer (online/in-person). This may be due to the course running for a shorter duration in summer than in spring (8 versus 16 weeks), enabling students to better retain the concepts in summer. Also, many students failing the course in spring that may be re-taking the course in summer, are already well versed in the subject, enabling them to perform better in summer. During the covid era, the combined percentage of students getting an 'A' or 'B' was less than in the post-covid era possibly due to restricted student-teacher communication during covid [8]. During covid, only one instructor was involved in teaching statics through online lectures, while post-covid there were multiple instructors for each semester. For instance, while comparing online classes in summer 2020, 11% got A and 27% got B, while in summer 2023, 24% got A and 34% got B.

The subsequent sections describe the syllabus, teaching and assessment techniques for each semester, followed by results and discussion. Given the vast application of this course to numerous engineering disciplines, it is important to assess the key factors affecting student performance. Therefore, improvements in student performance can be made by various means, including hands-on learning, changes in teaching and assessment methods, and guest lectures from industry, which would result in students having more interest in the subject.

2. Statics at OSU - Syllabus, Teaching and Assessment

Statics is a course that is taken by first year students of various engineering disciplines in most universities in the US. At OSU, this course is taught in the fall, spring and summer semesters. The prerequisites for enrolling in Statics is the successful completion of Physics and Math (calculus),

which the students either complete at OSU, or sometimes have completed in high school. The syllabus for all three semesters is similar, and briefly consists of the following topics:

a) Force vectors
b) Free body diagrams, equilibrium of a particle and resultant of forces
c) Rigid body equilibrium
d) Analysis of trusses by method of joints and sections
e) Internal forces in beams [shear force, bending moment]
f) Friction
g) Center of gravity, centroids and moments of inertia

For fall/spring, assessments are carried out based on homework, quizzes, attendance using 'iClicker', 3 exams and one final exam. Figure 1 shows a sketch, informing students how to complete their assignments. Typically, students are advised to complete their assignments on 'engineering paper', which makes it possible to present the calculations in a systematic and sequential manner.

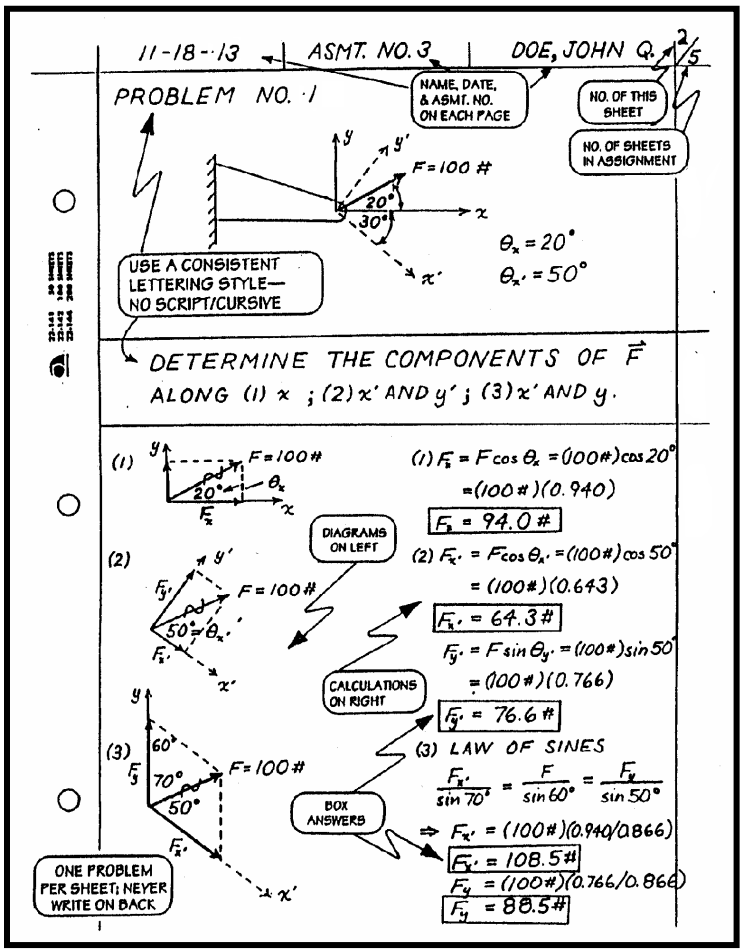


Figure 1. Suggestions to complete an assignment for Statics [from summer 2022 syllabus]

The assessment criteria for fall and spring semesters are similar, while being different for the summer semester. Fall and spring are in-person, while students enrolled in summer have the choice

of taking in-person or online classes. Also, fall/spring semesters last 16 weeks (15 weeks of class and 1 week break) with one-hour classes being held three times a week. Summer semester lasts 8 weeks, with classes being held four times a week.

The grading distribution for fall/spring is based on the following breakdown, with two grading options:

If the final exam grade is higher than the average of exams 1-3:

Homework	10%
Quizzes	5%
Attendance (iClicker)	5%
Common Exams 1-3 Average	35%
Final Exam	45%

If the final exam grade is lower than the average of exams 1-3:

Homework	10%
Quizzes	5%
Attendance (iClicker)	5%
Common Exams 1-3 Average	45%
Final Exam	35%

In summer semester (online/in-person), the assessment is carried out based on homework, quizzes, 3 exams and a final exam, with the following distribution:

Homework & Quizzes	20%
Exam #1	20%
Exam #2	20%
Exam #3	20%
Final Exam	20%

The final grades for fall, spring or summer semesters are based on the same criteria, as shown below:

A = 90 to 100
B = 80 to 89
C = 70 to 79
D = 60 to 69
F = Below 60

Unlike the summer semester, the fall and spring semesters involve a few classes that are separately devoted to discussion of a few examples and quizzes. Typically, at OSU, the enrolment of students is higher in fall than in spring, and less in summer. For instance, there were 335 students enrolled in fall 2022 and 186 students in spring 2022. In summer 2022, there were 13 students enrolled for in-person learning, while 26 students chose to take it online. Also, fall and spring semesters include ‘honors students’ that have certain additional requirements for the course.

Course requirements for honors students are set by the instructor and may include completing a short report based on attending a guest lecture or reading a research article. Students at OSU can enroll for the honors class only in fall and spring semesters. It is worth noting that, fall and spring semesters are taught by three instructors, while summer semester is taught by one, or sometimes two instructors. A summary for statics course delivery in fall/spring and summer semesters is presented in Table 1, followed by results and discussion.

While the syllabus is the tool that establishes the organization, content, and other details of the Statics course, it is essential to maintain constant and open communication among the instructors teaching the course in the same semester. This communication should involve sharing information about progress and student performance observed during the classes. In this way, small adjustments can be made to address specific issues, thereby contributing to the students' overall success. Each instructor, while adhering to the syllabus, will ensure a good outcome in the topics covered, while their personal teaching style will enrich the presentations in each session.

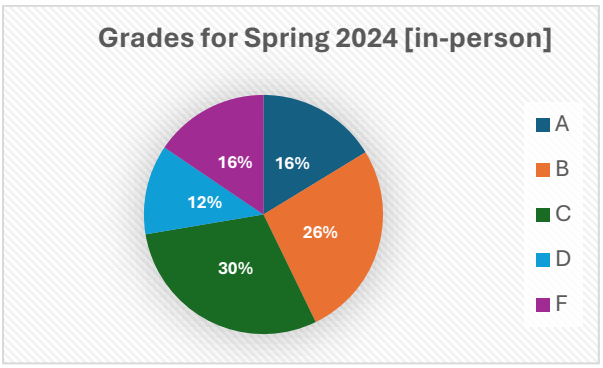
Table 1. Statics course delivery at OSU across various semesters

Fall/Spring Semester	Summer Semester
Taught by 3 instructors	Usually taught by 1 and occasionally 2 instructors
Typically > 200 students in each semester	Typically < 100 students [in-person + online]
In-person only	In-person or online [student can enroll in either of the two, but not both]
% Weightage of each component (e.g. homework, exam, quiz) is different	Weightage of each of the 5 components is the same (20%)
Classes are held 3 days a week, 50 minutes duration each	Classes are held 4 days a week, 1 hour and 15 minutes duration each
16 weeks [15-week class + 1 week break]	8-week class
Includes honors section	Does not include honors section

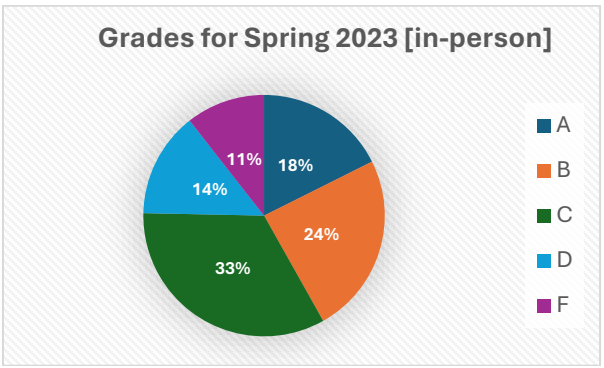
3. Results and Discussion

To assess the performance of students in statics at OSU, data from the post covid time (after 2021) and selected results during covid (e.g. 2020 and 2021) are presented and discussed in this section. Results are presented as pie-charts, displaying the percentage of students receiving a certain grade, for a given semester. For instance, Figure 2 shows that the combined set of students getting ‘A’ and ‘B’ in Spring semesters of 2024, 2023 and 2022 is nearly the same, although the failure rate is higher in 2022 (21% in 2022 v/s 16% in 2024). The reason for this could be that students just returned to in-person class in 2022, after covid.

On comparing performance of students in Fall 2021 and 2022 (Figure 3), it is observed that a greater percentage of students were top performers than in spring [30% getting ‘A’ in fall 2022 versus 17% in Spring 2022]. This could be due to students who attend summer classes of calculus and physics at OSU in summer, before enrolling in statics for the fall, making them better equipped to perform well.



a)



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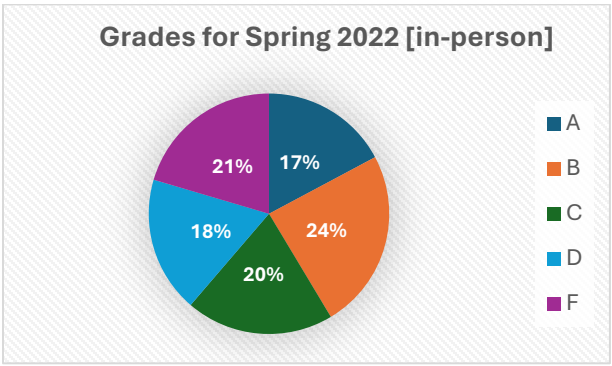
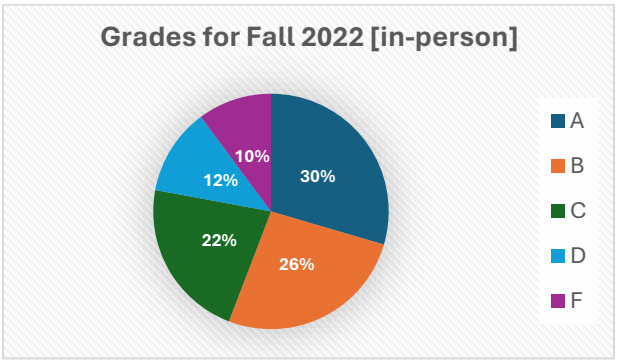


c)

Figure 2. Grades for Statics in Spring of: a) 2024; b) 2023; c)2022



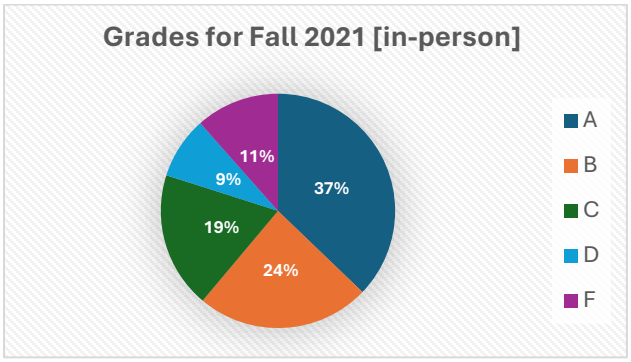


Figure 3. Grades for Statics in Fall of: a)2022; b) 2021

Performance of students in summer is generally excellent, with more than 50% of the student's getting 'A' or 'B' grades, for online or in-person classes (Figure 4). This performance is better than spring, where the combined percentage of students getting an 'A' or 'B' is less than 50%. This is likely because the summer course runs for 8 weeks instead of 16 weeks in fall/spring, which allows the student to stay focused for a short period of time and perform better. The other likely reason is that some students who were unsuccessful in passing the course in spring/fall are likely to enroll in summer. This allows these students to perform better in summer semester since they are studying the course for a second time, making it somewhat easier for them to perform better in summer.

Although there is no marked difference in the performance of students attending in-person or online, the latter may affect student performance due to limited interaction, as explained further. Figure 5 reflects the performance during covid outbreak that mainly relied on online class and one instructor, thus resulting in a higher failure percentage (22% in 2020 and 16% in 2021). Also, the combined percentage of students getting an 'A' or 'B' was found to be less than 50%. Results do indicate that there have been improvements in student performance, especially post-covid, although some recent developments can further this change, as described in the following section.

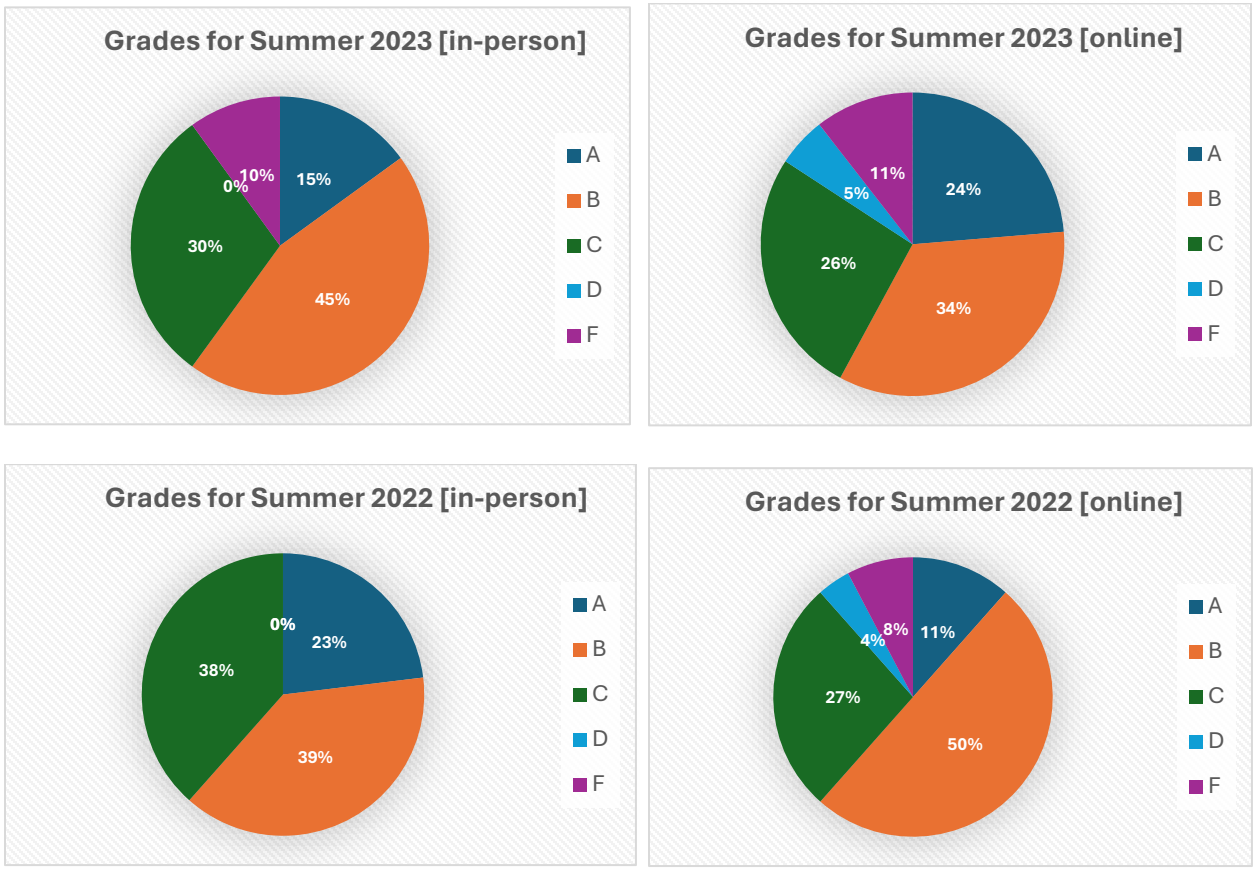


Figure 4. Grades for Statics in the Summer of: a) 2023 (in-person); b) 2023 (online); c) 2022 (in-person); d) 2022 (online)

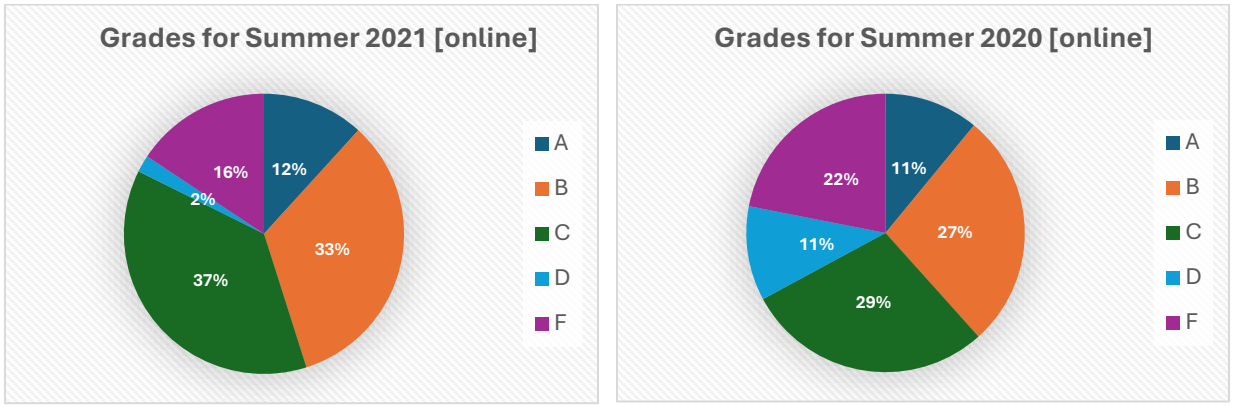


Figure 5. Grades for Statics during covid in Summer of: a) 2021; b) 2020

Factors influencing student performance

a. Online and in-person learning: While online learning during covid did affect student performance as shown in Figure 5, post covid showed some improvements in online learning (Figure 4). However, in-person learning provides greater interaction between student and instructor, or between student and teaching assistant (TA)/SI's, enabling students to learn more. Table 2 shows the percentage of students obtaining grades A, B and F in summer 2020 (online) and summer 2023 (in-person). Clearly, a higher percentage of students obtained an 'A' or 'B' for in-person classes than online classes. 22% of students failed the course while taking classes online, with only 10% of them failing the course during in-person learning.

Table 2. Percentage of students obtaining grades A, B and F during summer semesters

Summer 2020 (online)	11 % (A)	27 % (B)	22 % (F)
Summer 2023 (in-person)	15 % (A)	45 % (B)	10 % (F)

Table 3 presents student performances in summer semester during pre-covid (2018), covid (2020, 2021) and post-covid (2022, 2023). Data show that during covid the mean percentages in 2020 and 2021 were 70.33 and 71.61 respectively, with high standard deviations. High standard deviation during covid (e.g. 20.66 in 2020) indicates that there was a greater departure of marks from the mean values, obtained by several students in class. However, post covid performances were much better than pre-covid, as shown in summer 2022 (in-person), where the mean score of 83.24 and standard deviation of 6.72 were obtained. Pre covid mean values (74.19 in 2018) were also found to be better than mean percentages during covid. A higher negative value of skewness during covid (-1.82 in 2021) compared to post covid (-0.18 in 2022) indicates that the values are skewed to the left and majority of students obtained marks that were less than the mean value in 2021 compared to 2022. This indicates that online learning affected student performance during covid due to restricted student-teacher interaction.

Table 3. Student performance in summer semesters at OSU

Statistical parameter	Summer 2018 (in-person)	Summer 2020 (online)	Summer 2021 (online)	Summer 2022 (in-person)	Summer 2022 (online)	Summer 2023 (in-person)	Summer 2023 (online)
Mean	74.19	70.33	71.61	83.24	77.01	78.07	78.74
Median	79.18	76.44	76.67	84.84	84.99	81.49	83.00
Standard deviation	17.91	20.66	21.23	6.72	21.75	15.27	15.25
Kurtosis	4.14	1.26	3.04	-1.82	7.36	3.84	2.98
Skewness	-1.86	-1.30	-1.82	-0.18	-2.73	-1.79	-1.59

b. Summer and fall/spring classes: The classes in fall and spring last longer (15 week class and 1 week break) than in summer semester (8 weeks). The number of students getting an 'A' or 'B' is higher in summer than in fall, due to smaller classes in summer, allowing for greater student-teacher interaction. For instance, Table 4 indicates that there is no significant difference between spring 2024 and summer 2023 in percentage of students obtaining an 'A' grade. However, 45% of students obtained a 'B' grade in summer 2023 compared to only 26% of students in spring 2024. Furthermore, the percentage of failures in spring 2024 (16%) was higher than in summer 2023 (10%), indicating an improved performance in summer.

Table 4. Percentage of students obtaining grades A, B and F for in-person classes

Spring 2024	16 % (A)	26 % (B)	16 % (F)
Summer 2023	15 % (A)	45 % (B)	10 % (F)

c. Performance of honors students at OSU

At OSU, students can only register for honors classes in the fall and spring semesters and not during summer. Table 5 compares student performances in summer 2023 (non-honors) and spring 2024 (honors). Data shows that the mean percentage for honors students (81.58) is higher than those obtained by non-honors students (78.07 in-person; 78.74 online). Also, the standard deviation is lower for honors students (12.81) compared to non-honors students (15.25 online; 15.27 in-person), indicating less departure from the mean values for honors students compared to the non-honors section. A higher negative value of skewness for non-honors students (-1.79) compared to honors students (-0.82) indicates that the values are skewed to the left and majority of students obtained marks that were less than the mean value for non-honors students compared to honors students.

Table 5. Comparison of honors and non-honors student performances

Statistical parameter	Summer 2023 (in-person, non-honors)	Summer 2023 (online, non-honors)	Spring 2024 (in-person, honors)
Mean	78.07	78.74	81.58
Median	81.49	83.00	84.3
Standard deviation	15.27	15.25	12.81
Kurtosis	3.84	2.98	0.037
Skewness	-1.79	-1.59	-0.82

The improved performance among honors students is also attributed to students attending lectures, as indicated in Table 6. A null hypothesis between student attendance (variable 1) and final percentage (variable 2) is assumed (i.e. there is no relationship between variables 1 and 2). Since the P-value obtained from ‘t-test’ assuming equal variance is 0.017, which is less than 0.05, therefore null hypothesis is rejected. In other words, there is a strong relationship between students attending class and their performance in statics.

Table 6. Assessing statistical significance based on student performance and attendance

Statistical parameter	Value
Degree of freedom	82
P-value	0.017

4. Application of Statics for Architects and Architectural Engineers

Construction of buildings requires a thorough understanding of forces acting on the members and the load transfer mechanism from slab to beams, beam to column and column to foundation. Since architects and architectural engineers are closely associated with the design process, fundamental knowledge of statics is essential. At the School of Architecture (SOA) at OSU, models of various structures are constructed by students [see Figure 6(a)] to better understand the load paths in structural members. Figure 6 (b) shows an award-winning rendering of a soccer stadium presented

at the AISC/ACSA steel competition. According to the jurors of the competition, the structural double system was compelling and thought-provoking.

a) b)

Figure 6. (a) Truss model from Mola Structural used at the School of Architecture (SOA) at OSU for enhanced understanding of statics concepts. [source: molamodel.com]; (b) Rendering from an architecture students award winning work at the ACSA/AISC steel competition [from OSU Newsletter]

Students at the SOA are also involved in constructing models using 3D printing and REVIT models which helps in the understanding of the connection of various elements (beams, columns, slab) and the load transfer process. Undergraduate students from architecture and architectural engineering at the SOA have to take one design course in steel and concrete which requires knowledge of calculating the forces needed to design the member. Similarly, at the SOA, design studio courses involving architecture students have a set of instructors from architecture and architectural engineering backgrounds (see Fig. 7). This interaction helps architects better understand structural mechanics concepts which were learnt earlier during the statics course.

Figure 7. Architectural Engineering Professor John Phillips (co-author of this paper) at the School of Architecture (SOA), explaining structural engineering concepts to a student of architecture as part of the design studio course [picture from Spring 2023 SOA Newsletter].

With growing population, cities are expanding and the need for building construction has grown in most cities across the world. Furthermore, climate change has caused an increase in environmental events, including increased wind speeds, more seismic activity and increased snow/rain. The contribution of architects and architectural engineers in the construction of buildings, bridges and other structures is immense. Therefore, buildings must be able to sustain various structural loads (e.g. wind, snow, seismic, dead and live load) so that they are structurally adequate and provide occupant comfort. This makes it even more necessary for architects and architectural engineers to have a sound knowledge of statics, which can be used to estimate forces, which is the first step in the design process. Several steps have been taken recently at OSU to improve statics education among architects and other fields of engineering as discussed further.

5. Recent developments and recommendations for future

To enhance student performance in statics, several steps have been undertaken more recently at OSU, as discussed.

a) SI leaders: An undergraduate senior student that has excelled in statics previously is hired each semester to provide 'supplemental instruction (SI)'. These students called "SI leaders", are generally present in class during the lecture, and provide office hours that allow students to interact with them, in addition to office hours provided by the instructor and the TA. Studies have shown the efficacy of student-led discussions enhancing academic performance [9,10]. Students are encouraged to attend class, with availability of online resources, as well as textbooks from the library.

b) Hands-on learning and guest lectures: Although we have already conducted some brief hands-on experiences during the sessions on an individual basis, standardizing this experience for specific sessions would provide a better understanding of the concepts. Future work focused on hands-on learning and guest lectures from the industry could make the learning experience more interesting to students. For example, one could locate the centroid of a composite area or determine the static coefficient of friction between two surfaces using simple experiments. It has been proven that hands-on learning provides a better experience in the teaching-learning process, which can be explored for future work [11,12]. Currently only the honors' students in fall/spring have interactions with a few guest lecturers as part of their curriculum. If students can relate practical engineering applications to the principle of statics, it could improve their learning experience and enhance student performance. Figure 8 is an example of hands-on learning of the concept of vector decomposition by Coller [13]

Figure 8. Bathroom scale used in a vector decomposition activity [13]

c) International collaborations: More recently, OSU has launched an online learning program for statics held in summer, in collaboration with an overseas university. Figure 9 shows two of the instructors from the SOA at OSU involved in teaching statics to international students. This unique collaboration allows the instructors to teach both online and in-person, which is tremendously helpful in educating international students, besides encouraging cross-cultural collaborations.

Figure 9. Instructors from OSU teaching statics at an overseas university [photo obtained from OSU Facebook post]

d. Identifying concepts that are difficult to understand: Based on the authors' experience, some of the concepts in statics might be difficult to understand, which include drawing free body diagrams (FBD) and, signs of forces and resolution of forces in 2 and 3 dimensions.

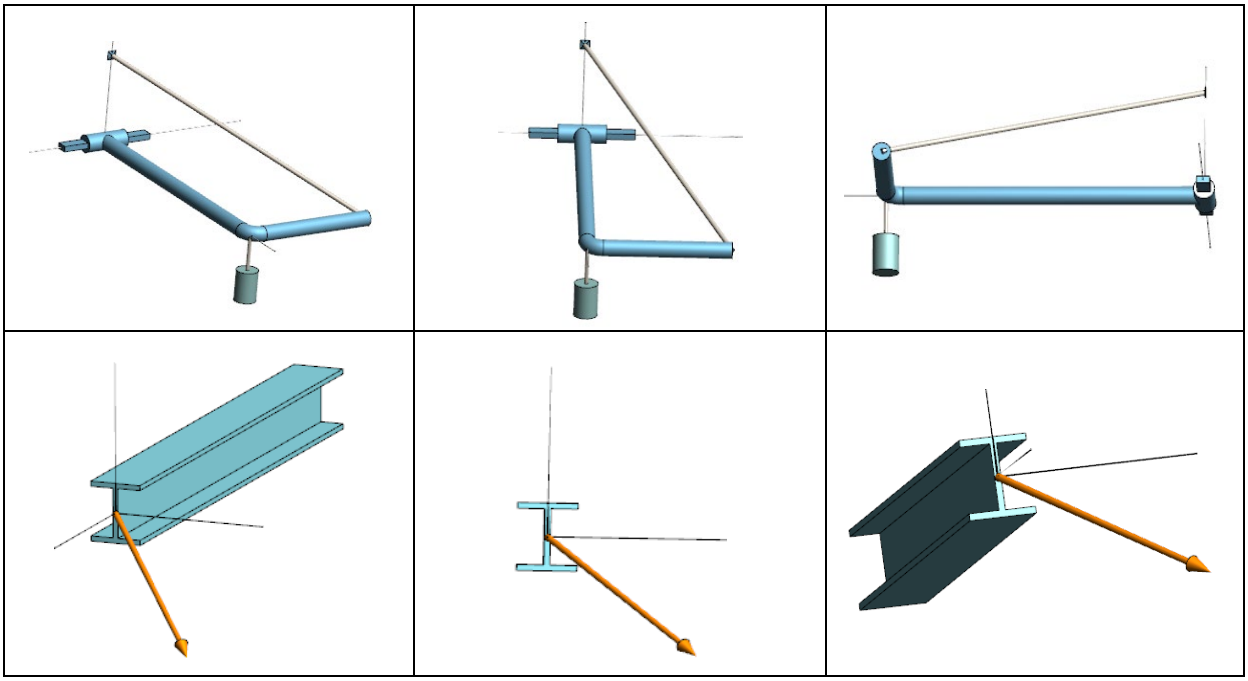


Figure 10. 3D diagrams created in SolidWorks and converted into PDF files. They are interactive and allow viewing the diagram from any angle.

Studies performed by Streveler et al [14] also found that besides FBD's, students found it difficult to comprehend concepts of static indeterminacy, external vs. internal forces, couples, static friction and the importance of signs on forces. Once the concepts difficult to understand are identified, it may be better to address them through additional examples. To address this issue, TA's and SI leaders conduct 'discussion classes' involving one-on-one discussion with students, and solving additional examples. The inclusion of interactive diagrams that can transition from 2D to 3D will be a valuable tool in enhancing the teaching-learning process (Fig. 10).

6. Conclusions

Statics is a common first year engineering course taught across various universities in the US, including OSU. Due to the application of statics in several engineering disciplines such as civil, architectural, aerospace and mechanical engineering, besides subjects including structural analysis and strength of materials, a solid understanding of the principle of statics is necessary. For this purpose, this paper looks at the student performance in statics at OSU, during pre-and post-covid times. At OSU, this course is taught in fall, spring and summer, with fall/spring lasting 16 weeks and summer lasting 8 weeks. Although the syllabus across all three semesters is the same, there are a few differences in terms of course delivery and assessment. Results indicate that the performance of students in fall and summer are generally better than in spring with a larger number of students obtaining 'A' or 'B'. In-person learning in the post covid times (after 2021) has resulted in improved student performance compared to covid times. A thorough understanding of statics can enable architects and architectural engineers to accurately estimate the forces acting on a building, which is necessary for the safe design and construction of buildings. Recent developments in the introduction of 'SI leaders' at OSU is a good initiative that is expected to see improvements. Future work focused on including hands-on learning and guest lectures from industry experts can enhance student learning in statics, leading to more engineers serving the society. Finally, although our experience in implementing brief experiments for the data in this article is still in its early stages, it is evident that the students are enthusiastic during the sessions. We believe that standardizing the experiments in class could promote an environment of improvement in the teaching-learning process for the subject of Statics.

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