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TL;DR Students don't read textbooks: designing online reference pages to enhance student learning

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TL;DR Students don't read textbooks: designing online reference pages to enhance student learning

Abstract

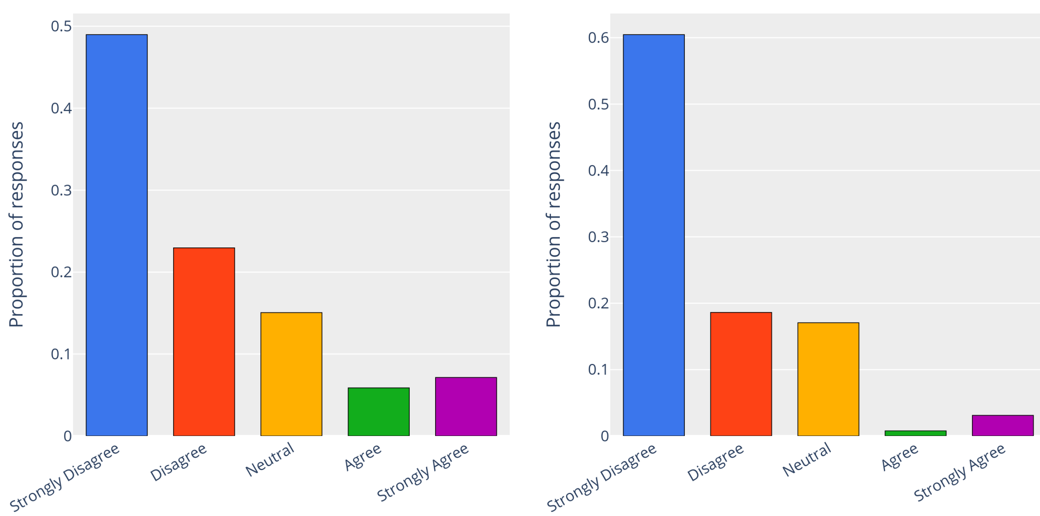
Open Educational Resources (OER) are transforming the higher education landscape by enabling equitable access to resources, increasing transparency of educational content, and reducing the financial burden on students. At a large public US university, low usage of textbooks by students has been observed, perhaps because traditional reading assignments were **Too Long**, many students **Didn't Read** (TL;DR). Centralized, free, and online OER were developed to try to increase student engagement outside of the classroom while providing consistency between courses and improving outcomes in the Kern Entrepreneurial Engineering Network's (KEEN) "3Cs" — Curiosity, Connections, and Creating value. These OER efforts included developing a series of reference pages that summarized key course concepts for three fundamental introductory mechanics courses: Statics, Dynamics, and Solid Mechanics. These reference pages are a short-format interactive resource tailored to the material taught at the university, thus ensuring uniformity with the lectures. They included definitions, key equations, expandable equation derivations, figures, and interactive animations. Key ideas were cross-referenced between courses, images and paragraphs were reused, and the same examples and applications were revisited and expanded upon. Such continuity across foundational courses reinforced students' comprehension of how concepts from each course are interconnected. With these features and guiding principles, the reference pages enhanced the educational experience with no financial burden to the students. With the growing popularity of digital note-taking devices, the reference pages were designed with mobile accessibility in mind. Student surveys and web-analytics revealed high satisfaction rates and usage of the course reference pages, and students' perception of the 3Cs significantly increased between the beginning and end of the semester.

Introduction

The rise of Open Education Resources (OER) has provided free, accessible, and adaptable educational materials that has allowed both students and instructors to break free from the constraints of traditional, costly commercial textbooks. The financial impact of commercial textbooks often causes students undue stress [1]. Beyond cost-saving, OER allow instructors to tailor content to their courses, rather than the course adapting to the textbook. This creates a more dynamic and relevant learning environment, with no negative impact on learning outcomes [2].

The Kern Entrepreneurial Engineering Network (KEEN) recognizes the need for engineering students to develop skills desirable by employers beyond the analytical capabilities taught in a standard engineering curriculum, such as communication and interdisciplinary thinking. The Entrepreneurial Mindset (EM) emphasizes the importance of these skills through the "3C's" framework — Curiosity, Connections, and Creating value [3]. Curiosity refers to one's willingness to continuously pursue new opportunities and ideas, challenge the status quo, and grow through errors and peer feedback. Connections is the ability to analyze information from a wide array of sources, recognize the intersection and interconnectedness of many concepts, and considering the broader environment. Creating value is the focus on fulfilling clear necessities and making a positive impact on others and themselves. Integrating this framework into students' engineering curriculum would allow them to acquire desirable soft-skills and better prepare them to make impactful contributions in their future careers.

At a large US public university, after observing lack of student use of the course textbooks (Fig. 1), an initiative was launched to create centralized online OER for three fundamental introductory mechanics courses: Statics, Dynamics, and Solid Mechanics. These courses are essential building blocks for engineering students, and the new resources aim to provide a consistent and engaging learning experience. The three courses had already been the focus of a successful structural overhaul in 2013 [4], increasing student engagement and perception of the course, decreasing faculty workload, and creating a community of practice (CoP) around these courses to further enhance the educational experience. The CoP oversaw the development of OER for Dynamics at that time, and students reported very high satisfaction with them. Dubbed "Mechref", for "Mechanics reference pages", this new initiative brought OER to the remaining two courses, as well as a platform for future course additions. This paper aims to determine (1) the efficacy of online reference pages, and (2) whether they improve outcomes in students' perception of the 3Cs.



(a) Statics

(b) Solid Mechanics

Figure 1: Survey responses to the question "I make use of the recommended textbook", Fall 2024

The online reference pages

Existing mechanics OER [5], [6] act as a free alternative to paid commercial textbooks, alleviating the financial burden imposed upon students. However, the reference pages format strikes a middle-ground between a textbook and lecture notes, providing context beyond a slideshow, but with brevity in mind [7]. The shorter format aligns with students' penchant towards concise summaries over lengthy readings — reflected in the popular acronym TL;DR or Too Long; Didn't Read, usually indicating a person skipped a large piece of text due to its wordiness. The goal is to promote the different aspects laid out in the 3Cs framework.

Designed with continuity in mind, the pages reuse and connect concepts, examples, and figures across courses. This reinforces core ideas while demonstrating applications in diverse contexts, with the aim to strengthen students' understanding of concepts and highlight the interconnectedness of their studies.

The online aspect is critical. As opposed to printed material, the reference pages provide interactivity in the form of videos and animations, easy navigation with a search feature and a clickable table of contents, and links to other websites so students can quickly learn about extensions of the material and real-world applications. "Callout cards" — blue boxes right of the content (Fig. 2), are meant to facilitate linking to other pages or external resources. By providing additional information, clarifications, and showcasing related examples side-by-side with the relevant content, the team hopes to foster students' curiosity and connection to their future careers as engineers.

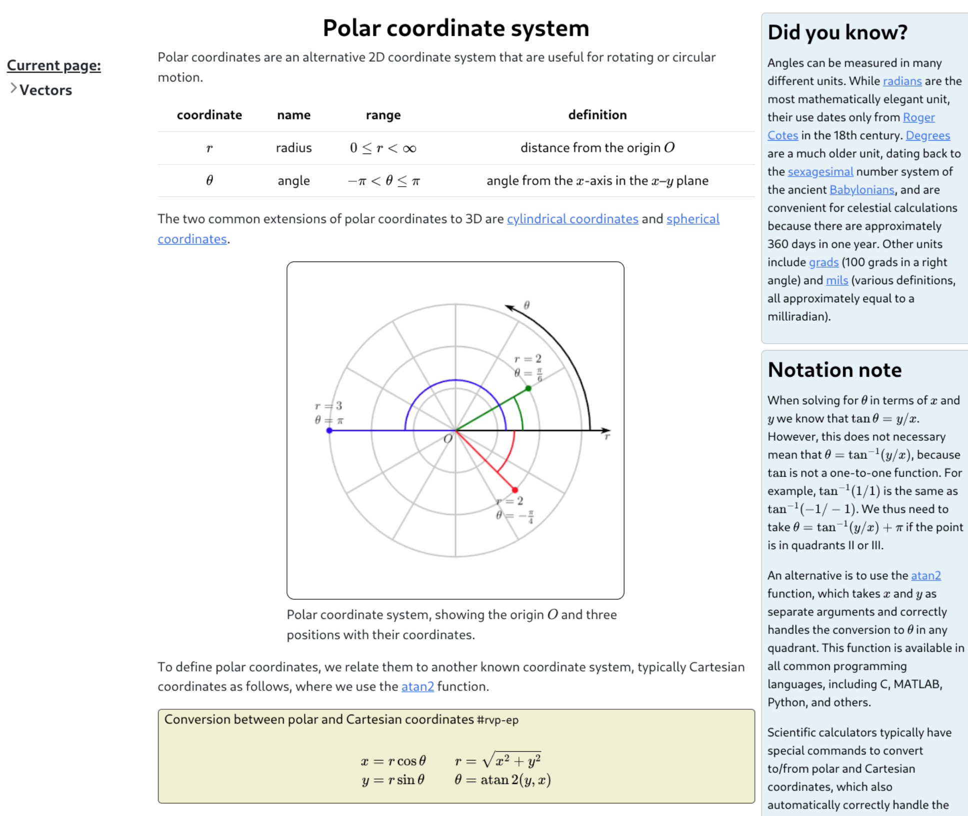


Figure 2: Example page containing figures, callout cards, and relevant equations

As previously mentioned, animations are a pivotal tool used to illustrate certain hard-to-visualize concepts (Figure 3). Most were developed using an in-house-tool, but the pages also support interactive graphs using Plotly [8]. Example problems were added throughout the pages so students could check their understanding of the content and provide additional quiz practice.

With the growing use of digital note-taking devices, the pages aim to maximize mobile accessibility. Unlike heavy printed textbooks, which can be inconvenient and impractical to carry around, the mobile-friendly online pages ensure students can easily access them anywhere at anytime, and are easy to integrate into their studying habits.

The initial working version of the website itself was developed over the course of less than a month by an undergraduate student under the supervision of the professor who had developed the previous pages introduced in 2013. Additional features were developed and introduced slowly thereafter. The content for each course was developed collaboratively between instructors who had taught the class and graduate teaching assistants in two months. It was then converted from LaTeXto HTML. Logistically, the pages also provide fast editing capabilities, enabling continuous improvement at virtually no cost.

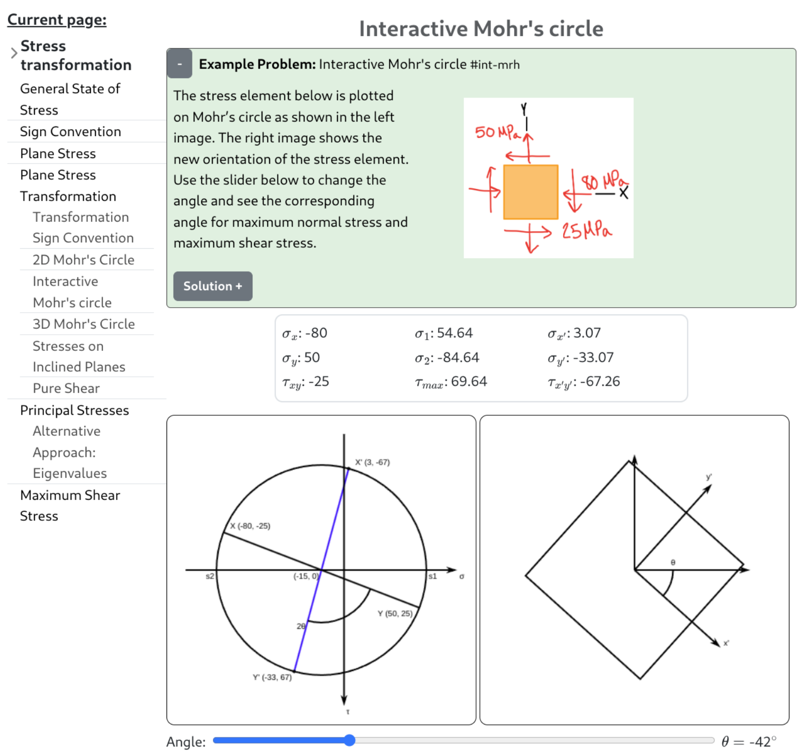


Figure 3: Example page with table of contents, example problem, and interactive animation with a slider bar illustrating Mohr's circle, historically one of the hardest concepts for students.

Methods

The initiative was focused on three sophomore-level courses during the Fall semester of 2024 — Statics, Dynamics, and Solid Mechanics, with Statics being a prerequisite for the other two courses. Statics had a unique structure by being separated into two groups depending on major, where one was enrolled for 10 weeks and the other for the entire 16-week semester. Both groups could register in either of the two available lecture sections. Solid Mechanics and Dynamics both had a standard course structure and were semester-long courses.

All three courses had a weekly discussion section, in which students would collaborate to solve worksheet problems. The courses also had a weekly homework deadline — Wednesday for Statics and Solid Mechanics, and Monday for Dynamics. Students were encouraged to use the reference pages when working on the worksheets and homework. Every course also featured a bi-weekly quiz taken inside of a computer-based testing center, where students could choose the date and time within a pre-defined three-day window — Wednesday to Friday in Statics, Tuesday to Thursday in Dynamics, and Thursday to Saturday in Solid Mechanics. Each course had a final exam as well, taking place during the 11th week (after the first section ended) for all students in Statics, and at the end of the semester for Solid Mechanics and Dynamics, during a window spanning from the end of the 15th week to early in the 16th week. Students had access to the reference-pages during the quizzes and final exam. The structure and material have been consistent across semesters, ensuring continuity and minimizing differences between instructors.

Two lecture sections were held in Statics, both with different instructors. One instructor was a newly appointed professor with a PhD in Mechanical Engineering, while the other had 5.5 years of experience as a professor and a Doctorate in Aerospace Engineering and Mechanics. Dynamics and Solid Mechanics both had a single instructor. The former was taught by a professor of 7 years with a PhD in Mechanical Engineering. The latter was taught by a new faculty member with a PhD in Civil Engineering and over a decade of industry experience, licensed as a Professional Engineer and Structural Engineer.

Two surveys were conducted to gauge student use of the reference pages and their perception of the 3Cs — the first during the 6th week and the second during the 15th week. Students were given the first ten minutes of their weekly discussion section to respond to the survey, neither compensation nor penalties were given based on whether a specific student answered or not. Responses were anonymous. This study was reviewed by the university's Institutional Review Board and determined to be exempt from Human Subjects Research (IRB23-0162). Both surveys had over 1,000 responses combined as illustrated in Table 1. This corresponded to a 68% and 45% response rate in Statics, 65% and 43% in Dynamics, and 69% and 65% in Solid Mechanics for the first and second surveys, respectively. Demographic questions were only asked during the first survey, and were optional. "Other" responses were discarded for "Yes/No" questions, and percentage values are relative to the total number of valid responses for that question, not to the total number of responses. Students were asked to respond on a Likert scale (from 1 - Strongly disagree to 5 - Strongly agree) to the following questions:

- Q1: I make use of the course online reference pages (Usage)
- Q2: The reference pages stimulate my curiosity about real world problems. (Curiosity)
- Q3: The reference pages help me understand how concepts in the course connect to each other. (Connections)

- Q4: The reference pages help me understand how the course content relates to my role as a future engineer. (Creating value)

The results for both surveys were compared using t-tests for means to assess whether reference page usage throughout the semester affected the responses to the above questions. To simplify illustrations, data from the original Likert-scale was aggregated, where 1 & 2 were combined into "Disagree", 3 remained "Neutral", and 4 & 5 were combined into "Agree".

Table 1: Demographics of responding surveyed engineering students

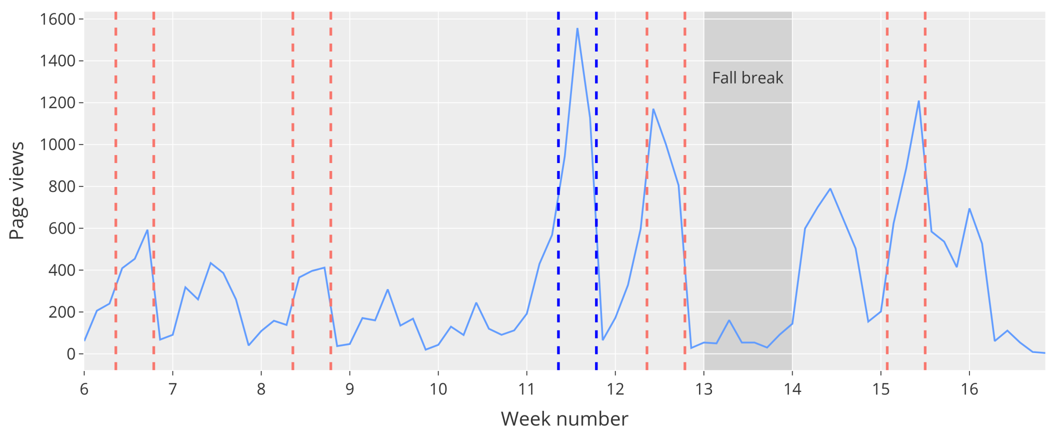
Variable		**Start**		**End**		**Total**	
		n	**(%)**	n	**(%)**	n	**(%)**
Course	Total	683	100%	360	100%	1043	100%
	Statics	425	62%	154	43%	579	56%
	Dynamics	129	19%	85	24%	214	21%
	Solid Mechanics	129	19%	121	34%	250	24%
Sex	Female	168	32%			168	32%
	Male	340	65%			340	65%
	Other	13	2%			13	2%
Race	White	227	46%			227	46%
	Asian	139	28%			139	28%
	Black/AA	16	3%			16	3%
	Hisp./Latino	65	13%			65	13%
	Other	44	9%			44	9%
Years at university	<1	19	4%			19	4%
	1-2	497	94%			497	94%
	2-3	10	2%			10	2%
	3-4	2	0%			2	0%
Transfer	Yes	19	4%			19	4%
	No	497	96%			497	96%
International	Yes	57	11%			57	11%
	No	457	89%			457	89%

Visitorship data was also gathered starting in the 6th week using Google Analytics in the form of page views per day. Even though students could access the reference pages during the quizzes and final exam, traffic data does not include visits from computers inside the testing center. In Statics, data gathered after the end of the first section was scaled to reflect the change in enrollment numbers (627 vs. 339). It was then plotted against quiz windows to determine whether students were more likely to use the pages to study for their quizzes, and paired T-tests were performed to compare the mean visitorship during quiz and non-quiz weeks. The data was then averaged for every weekday and aggregated into whether the days were during an quiz week or a non-quiz week. Consistent with the goals to provide a good experience on mobile devices, the proportion of users accessing the reference pages using mobile devices was also measured.

Results

Students in all three courses used the reference pages significantly more during weeks where they had a quiz compared to weeks without a quiz (Table 2). This trend amplified as the semester went on, reflected by an increase in peak visitorship as the semester continued (Fig. 4).

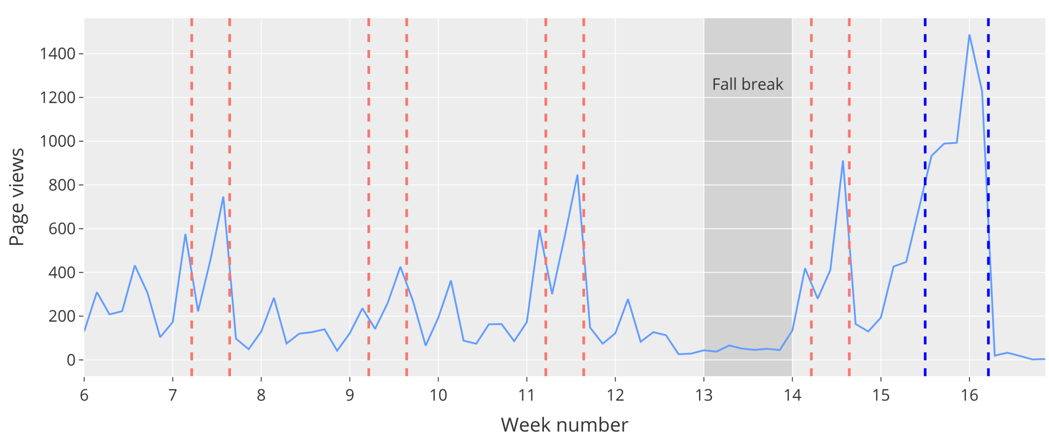
Across all three courses, average daily page views during the quiz window were significantly higher during quiz weeks vs. non-quiz weeks — $p < 0.05$ for all three courses (Table 2). Additionally, significant improvement in survey agreement between the start and the end of the semester can be observed in all but two question-course pairings (Table 3). Students accessed the pages from a computer 80.2% of the time, a phone 16.4%, and a tablet 3.3%.



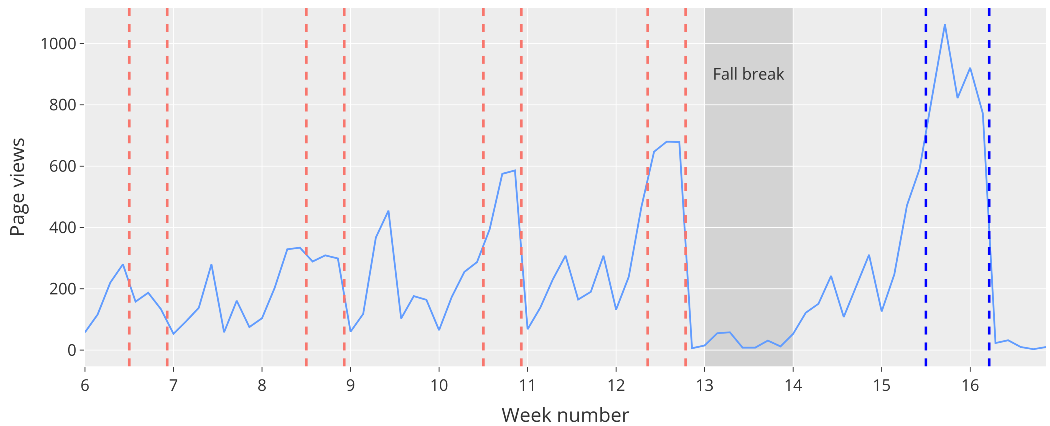
(a) Statics page views per day

Statics

With regards to visitorship, Statics started with only a small difference between quiz and non-quiz weeks. This trend continued until the final exam/end of the first section, and large peaks can be seen during subsequent quiz windows (Fig. 4a). Visitorship prior to the quiz window remained similar during quiz and non-quiz weeks, but a large divergence in visitorship is observed during



(b) Dynamics page views per day



(c) Solid Mechanics page views per day

Figure 4: Daily page views from the 6th week to end of semester, with quiz and final exam windows highlighted by red and blue dashed lines, respectively

Table 2: Paired T-test results for comparison of mean page views ($\mu_{quiz} > \mu_{noquiz}$) during weeks with and without exams, excluding final exam and Fall break, $\alpha = 0.05$

Course	μ_{quiz}	μ_{noquiz}	T_0	p
Statics	451.2	256.0	2.276	**0.0134**
Dynamics	321.5	162.2	3.209	**0.0011**
Solid Mechanics	293.0	175.2	2.845	**0.0031**

the quiz window (Fig. 5).

The largest differences in responses between the start and end surveys were observed in Statics (Fig. 6). Sharp improvement can be seen in usage (start: 37% vs. end: 68%), perceived interconnectedness of the material (start: 30% vs. 64%), and relevance to students' future career (start: 31% vs. end: 47%). However, a decline can be seen in agreement that the pages stimulated curiosity about real-world problems (start: 43% vs. end: 34%), with disagreement increasing by almost as much as agreement declined (start: 16% vs. end: 29%), and neutrality not changing much (start: 41% vs. end: 38%).

Dynamics

Dynamics saw consistent traffic peaks during exam weeks (Fig. 4b). A large gap on the first day of the quiz window widened steadily throughout the period, reaching a 3.5x increase in visitorship during quiz vs. non-quiz weeks (Fig. 5) on the last day. Similar levels of traffic can be observed after the quiz window, with a peak during both quiz and non-quiz weeks on the subsequent Monday, the weekly homework deadline.

Every question saw significant improvement in Dynamics (Fig. 6). Already seeing a large proportion of student usage at the beginning of the course, the reference pages became nearly universally used at the end of the semester (start: 81% vs. end: 95%), with only 1% disagreement. Students agreed more (start: 57% vs. end: 76%) and disagreed less (start: 13% vs. end: 7%) that

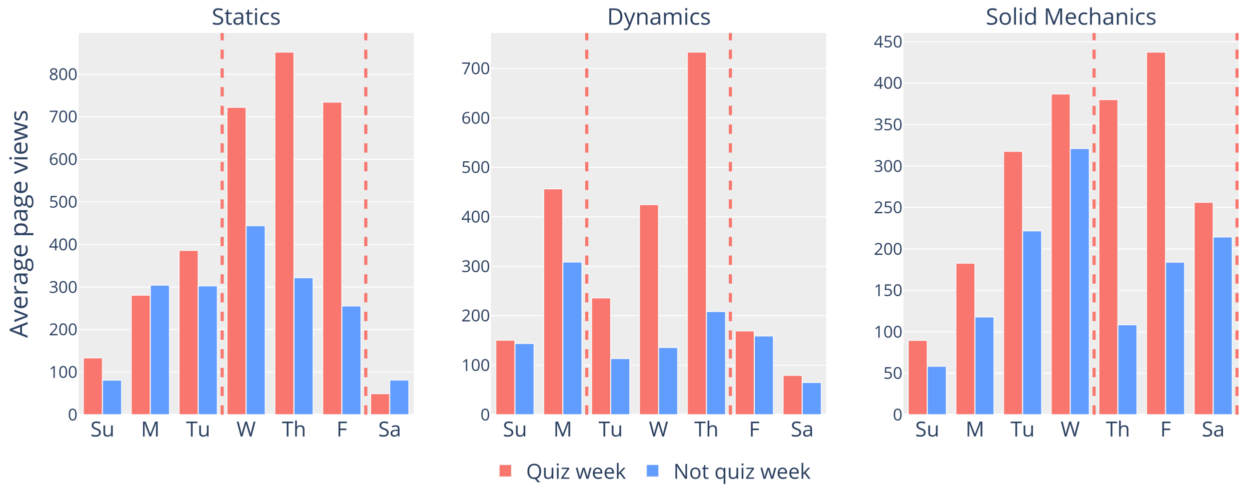


Figure 5: Number of visitors to the reference pages per day during quiz and non-quiz weeks, quiz window highlighted by red dashed lines, excluding final exam and Fall break

Table 3: Paired T-test p-value for comparison of means ($\mu_{end} > \mu_{start}$) from Likert-scale survey at the beginning and end of semester for all survey questions, by course, $\alpha = 0.05$

Question	Statics	Dynamics	Solid Mech.
I make use of the course online reference pages	**<0.001**	**<0.001**	**0.01757**
The ref. pages stimulate my curiosity about real world problems	0.96205	**0.00127**	0.21947
The ref. pages help me understand how concepts in the course connect to each other	**<0.001**	**0.01626**	**0.00299**
The ref. pages help me understand how the course content relates to my role as a future engineer	**<0.001**	**0.01316**	**0.00544**

the reference pages illustrated how concepts within their courses were connected. An almost equal increase in agreement was measured in stimulation of curiosity for real-world problems (start: 40% vs. end: 55%) and (start: 45% vs. end: 59%), and a similar decrease in disagreement was also measured (start: 23% vs. end: 11%, and start: 27% vs. end: 13%).

Solid Mechanics

Peak visitorship to the Solid Mechanics reference pages grew steadily throughout the semester, with the troughs remaining at a similar level (Fig. 4c). Traffic also rose from the start of the week up until the day prior to the quiz window, when a divergence can be observed between quiz and non-quiz weeks — traffic during non-quiz weeks plunged by 66% from the day prior to the start of the quiz window (Fig. 5), while during quiz weeks it remained constant from throughout the quiz window, decreasing slightly on the last day.

All but one question saw a significant increase in Solid Mechanics (Fig. 6). A similar increase in usage to near-universal levels (start: 84% vs. end: 92%) as in Dynamics was measured, however disagreement only moved slightly (start: 5% vs. end: 4%). Students agreed more (start: 60% vs.

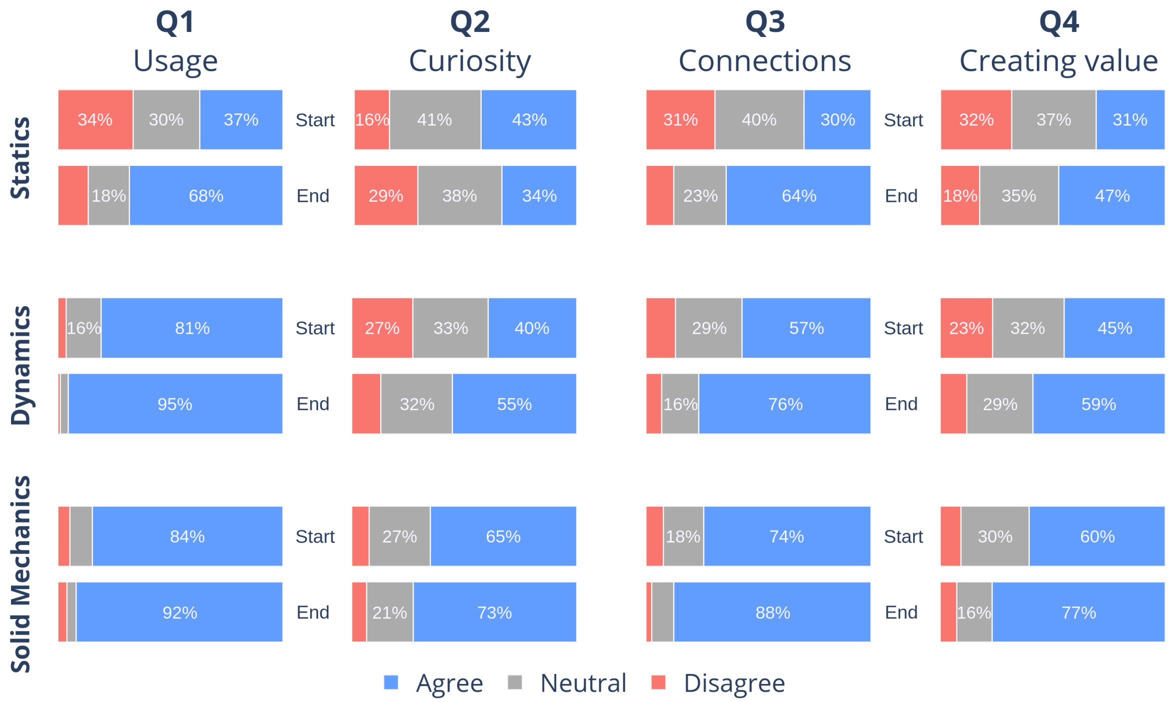


Figure 6: Proportion of students who agreed/disagreed for each question, per course

end: 77%), were neutral less (start: 30% vs. end: 16%), but disagreed less only slightly (start: 9% vs. end: 7%) that the pages helped them relate course content to their future careers. Agreement rose (start: 74% vs. end: 88%) and disagreement fell (start: 8% vs. end: 2%) when asked about the interconnectedness of the class. The only question that did not yield significant results in Solid Mechanics was whether students felt that the pages stimulated their curiosity about real-world problems, with agreement rising (start: 65% vs. end: 73%), but disagreement remaining fairly steady (start: 8% vs. end: 6%).

Discussion

Statics

With the first few weeks consisting of reviewing vectors and therefore having few formulae, it is no surprise that usage of the reference pages started at a lower level compared to the other courses during that period. However, with the difficulty increasing throughout the course, and especially in the second part — with topics such as fluid pressure, virtual work, and centers of mass of continuous shapes, a large rise in traffic and perceived usefulness of the pages was observed, in all but one category.

This course also contained the only question with a decline in agreement — on the topic of sparking curiosity in real-world problems. This may be due to the fact that the topics covered towards the end of the class became more conceptual, and that topics from week 5 to week 10 consisted of different variations and applications of $\sum \vec{F} = 0$.

Covering a wide-range of foundational topics, rather than higher-level concepts, may partly explain why the course had the lowest rates of agreement in perceived usefulness of the material in their future careers. Additionally, students from majors required to be in the second-half of the course may see these topics as less applicable to their studies than those only required to be in the shorter section, which could explain the drop in the second survey.

Dynamics

Visitorship in Dynamics followed a similar pattern throughout the period from the 6th to 14th week — high peaks during quiz windows and smaller peaks at the weekly homework deadline, with the heights of both remaining almost equal from week to week. Having had some version of the reference pages for a decade, the pages were already ingrained in the course's culture, with both students and instructors already being very familiar with their existence, perhaps explaining the steady levels of traffic.

Dynamics had the highest end-of-semester usage rate of all three courses, and agreement rose significantly in all three questions (Table 3).

The largest rise in agreement for the question about sparking curiosity in real-world applications occurred in Dynamics. The conceptual nature of the course meant that the reference pages provided the perfect opportunity to showcase concrete examples. Furthermore, the previous pages having been developed over 10 years ago also meant that there had been plenty of time to add and perfect numerous examples, which were carried over to the new version. The numbers reflected the positive response by students to these efforts.

Solid Mechanics

In Solid Mechanics, a very interesting trend can be observed in the number of page views — the heights of each quiz-window traffic spike seem to almost increase linearly. This reflected a steady increase in the usage of the pages as both the students and course staff became more familiar with the resource, while students' perceived usefulness of the pages may have also grown over time.

Solid Mechanics had the largest agreement levels at the end of the semester for every question except Q1, being narrowly exceeded by Dynamics, although not significantly ($p = 0.668$).

With the topic of Combined Loading in week 11 requiring knowledge of every single prior topic, the reference pages were able to link to and use prior concepts from the course, effectively showcasing the interconnectedness of the course. This led to Solid Mechanics having the highest agreement on Q3, 12%pt higher than Dynamics ($p = 0.0012$) and 24%pt higher than Statics ($p < 0.001$).

The question about stimulating curiosity for real-world problems had the only non-statistically significant increase, pointing to perhaps needing to better leverage the reference pages by adding additional examples and animations. Existing examples focusing on traditional simple structures such as beams and bridges could be modified into more concrete ones, and additional interesting examples incorporated into the pages to improve outcomes on this question.

Overall

Questions 2 & 4 on Curiosity and Creating value had the lowest levels of agreement among the 3 Cs. This shows additional work needs to be done beyond the first semester to continuously improve the reference pages in these areas. Concrete additional example problems and scenarios — avoiding very generic ones like bridges and beams — could be added to improve students' curiosity about real world problems. Furthermore, recognizing the fact that many different majors are enrolled in the introductory mechanics sequence, having multiple examples where each major can easily relate to at least one of them could prove very useful in increasing students' perception of the material's usefulness in their careers.

Question 3 on Connections was the C with the highest level of agreement among all three. This clearly showcased the strengths of the online aspect, being able to quickly link to any section within the pages themselves. Outside of the 3 Cs, question 1 alongside Figure 4 show that the longer students were exposed to the reference pages, the higher the likelihood students' used them.

Conclusion

The levels of agreement on whether the reference pages improved outcomes in the 3Cs rose significantly the longer students were exposed to the pages in almost all cases (Table 3). This reinforces the idea that in the era of declining textbook use, the reference page framework, a free short-form interactive online textbook, could be useful in significantly increasing student engagement with the material outside of the classroom and improve positive outcomes. The short format also allows for fast development of the content.

After seeing traffic and usage statistics, multiple instructors from other courses — thermodynamics and two third-year mechanical design classes — have reached out to be part of this initiative and have been integrated into Mechref, doubling the nuber of courses and demonstrating the buy-in from both students and faculty.

Limitations to our study lie in the data collection process. A student frequently switching between multiple pages could inflate the visitorship count. Having traffic data from the 2013 iteration of the Dynamics pages to compare against would have allowed for a direct comparison, and helped determine whether mobile accessibility resulted in increased usage. Additionally, potential differences between the two student cohorts in Statics — those enrolled for 10 weeks versus the full semester — may skew the survey results for that course in either direction.

This study was done on the framework of the pages as a whole. Further research is needed to understand the impact of the reference page content (i.e., animations, example problems, and real-world applications) on each of the 3Cs, as well as how future changes to the content effect student perceptions.

Resources

"Reference pages" - *i.e.,* course content - has been created for this project on our own website. These pages contain online educational materials that enhance student curiosity, connection and creates value for both student and instructor. These pages can be freely used, adopted, and if desired modified, by anyone for use in their courses under the Creative Commons CC BY-NC license [9].

References

[1] J. J. Jenkins, L. A. Sánchez, M. A. K. Schraedley, J. Hannans, N. Navick, and J. Young, "Textbook Broke: Textbook Affordability as a Social Justice Issue — Journal of Interactive Media in Education — jime.open.ac.uk," *Journal of Interactive Media in Education*, 2020, [Accessed 06-01-2025].

[2] V. Clifton and S. Khan, "Efficacy of Open Textbook Adoption on Learning Performance and Course Withdrawal Rates: A Meta-Analysis," *AERA Open*, 2019, [Accessed 06-01-2025].

[3] J. S. London, J. M. Bekki, S. R. Brunhaver, A. R. Carberry, and A. F. McKenna, "A Framework for Entrepreneurial Mindsets and Behaviors in Undergraduate Engineering Students: Operationalizing the Kern Family Foundation's "3Cs"," vol. 7, no. 1. [Online]. Available: https://eric.ed.gov/?id=EJ1199586

[4] M. West and G. L. Herman, "Sustainable reform of "introductory dynamics" driven by a community of practice," in *2014 ASEE Annual Conference & Exposition*, no. 10.18260/1-2–23081. Indianapolis, Indiana: ASEE Conferences, June 2014, https://peer.asee.org/23081.

[5] D. Baker and W. Haynes. Engineering Statics — Open & Interactive. [Online]. Available: https://engineeringstatics.org/

[6] Dollár, A. and Steif, P. Engineering Statics — Open + Free. [Online]. Available: https://oli.cmu.edu/courses/engineering-statics-open-free/

[7] Mechanics reference pages. [Online]. Available: https://mechref.org

[8] Plotly, "Plotly - Python Graphing Library," 2025. [Online]. Available: https://plotly.com/python/

[9] C. Commons. Attribution-noncommercial 4.0 international (cc by-nc 4.0). [Online]. Available: https://creativecommons.org/licenses/by-nc/4.0/