The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center
Portland, OR . June 23 - 26, 2024
Paper ID #42050

Exploring Intervention Research in Statics Courses: A Systematic Review of ASEE Publications from 2013 to 2023

Mr. Ibrahim Nihad Awartani, University of Cincinnati

Ibrahim Awartani is a fresh first-year international doctoral student pursuing Engineering Education in the Department of Engineering and Computing Education at the College of Engineering and Applied Sciences at University of Cincinnati. His bachelors background is a Mechanical Engineering degree from Philadelphia University in Jordan. His masters background is a Master's of Sciences in Engineering Management from Eastern Michigan University. He has had a few years of experience in the construction and consulting fields as an MEP and stakeholder manager. His research interests are focused on course interventions, concept inventories, international curricula, accessibility, and course climates.

Iman Shayegani, University of Cincinnati

Iman Shayegani is a Ph.D. student at University of Cincinnati. He received his Bachelor's degree in Electrical Engineering from University of Tehran and his Master's degree in the same field from Shiraz university. He had been an educational consultant and a mathematics teacher for over 10 years in Iran, and helped more than 1000 people to become successful in the University Entrance Exam before starting his Ph.D. program. Based on his experience in working with students and his academic background in electrical engineering, he is trying to find suitable methods of learning for engineering students especially in the electrical engineering field.

David Allen Evenhouse, University of Cincinnati

Dr. David Evenhouse is an Assistant Professor-Educator at the University of Cincinnati College of Engineering and Applied Science, Department of Engineering and Computing Education. He primarily teaches introductory engineering courses at UC's Clifton Campus and at Chongqing University, China, as part of their cross-institutional Joint Co-op Institute. He received his Engineering Education PhD and Mechanical Engineering MS degrees from Purdue University in 2020 and 2021, respectively, and graduated from Calvin College in 2015 with a B.S.E. concentrating in Mechanical Engineering. Beyond instruction, he continues to pursue research on workforce development, student outcomes, and student experience in context with innovative instructional technologies and practices.

Dr. So Yoon Yoon, University of Cincinnati

Dr. So Yoon Yoon is an assistant professor in the Department of Engineering and Computing Education in the College of Engineering and Applied Science at the University of Cincinnati, OH, USA. Dr. Yoon received her Ph.D. in Gifted Education, and an M.S.Ed. in Research Methods and Measurement with a specialization in Educational Psychology, both from Purdue University, IN, USA. She also holds an M.S. in Astronomy and Astrophysics and a B.S. in Astronomy and Meteorology from Kyungpook National University, South Korea. Her work centers on elementary, secondary, and postsecondary engineering education research as a psychometrician, data analyst, and program evaluator with research interests in spatial ability, STEAM education, workplace climate, and research synthesis with a particular focus on meta-analysis. She has developed, validated, revised, and copyrighted several instruments beneficial for STEM education research and practice. Dr. Yoon has authored more than 80 peer-reviewed journal articles and conference proceedings and served as a journal reviewer in engineering education, STEM education, and educational psychology. She has also served as a PI, co-PI, advisory board member, or external evaluator on several NSF-funded projects.

Exploring Intervention Research in Statics Courses: A Systematic Review of ASEE Publications from 2013 to 2023

Abstract

Statics is a foundational subject for many engineering students, exposing students to mathematics and physics of design and planning settings, which is vital for mechanical, civil, and aerospace engineers. This study systematically collected, analyzed, and reviewed the most recent 10-year ASEE conference papers about interventions in Statics courses. A total of 37 papers were selected, categorized, and then coded based on a set of inclusion/exclusion criteria. We found that the majority of the interventions were practice/research-based interventions with almost 62% of papers reporting significant outcomes. In addition, COVID-19 not only affected many studies' implementation, but also their methods, as most studies during the lockdown period were qualitative. 13 papers using pre-post assessment methods reported the most significant outcomes, but many did not properly use a control group. The findings of this study are expected to help determine which interventions were especially effective in improving student outcomes based on reported results as well as propose future implementation ideas. This paper was made to be the first to establish clearer insight regarding interventions in Statics education.

Keywords: engineering education, Statics, intervention, systematic review

I. Introduction

Students of mechanical, civil, environmental, aerospace, and industrial engineering disciplines are mandated by the ABET standards to take many common courses laying down the same theoretical foundation across all disciplines (ABET, 2022). This has been the standard for course design for decades since the advent of pre-requisite courses that lay the foundation for later courses in the curriculum (Skinner, 1954; Sato et al., 2017). One of those courses is the Engineering Statics course, which is also known by alternative names, such as Statics and Dynamics, Mechanics of Materials, Structural Elements and Loading, and other varieties unique to their universities. The Britannica encyclopedia (Stevin, 2019) states the course is a sub-division of physics and its history is founded on Archimedes theories that were later expanded on with Newton's first, second, and third laws. The encyclopedia expands on what makes this course so foundational for Engineering as the main competency for the course is providing the analytical and graphical procedures needed to identify and describe the unknown forces acting on stationary objects. For this paper, we will refer to this course as Statics as a general title of all relevant courses offered at higher institutions in the U.S.

A Statics course is a major steppingstone and a pre-requisite for much of the engineering curriculum (Yoon et al., 2019). Topics include Static equilibrium, resolution of forces, loading systems, free body diagrams, moments and force couples, and vector applications, among others. The classical mechanical topics are derived from Newton's three primary laws and are vital to any up-and-coming engineer, especially in the abovementioned disciplines.

Despite requiring hundreds of students to funnel through the same course, instruction is complicated by the fact that individual students learn differently from one another (Thorndike, 1910). Efforts to better understand and improve student learning have led to the development of a variety of research-based teaching methods and philosophies in the field of engineering education. With such philosophies in a growing field of study, faculty can give students new experiences and teaching methods through course interventions. For this study, to avoid confusion with other definitions of course interventions, we defined an intervention in higher education as follows: An action or change conducted by an instructor to address an area of concern, to test for possible improvements, or to study the effects the action or the change on students. These interventions can be recognized when they are researched, documented, and published, such as through the American Society for Engineering Education (ASEE) conference papers and journals.

While there have been many published ASEE conference papers on Statics course interventions, we could not find a systematic review of intervention research in engineering Statics courses. As a result, we aimed to address this gap in the current literature to further establish and elaborate on course intervention findings through a systematic review.

Purpose of Study

This study conducted a review on interventions published in ASEE conferences within the past ten years in the foundational Engineering Statics course. We chose to only cover conference papers for the period between 2013 and 2023 as a first review to assess the current state of the research and the potential to conduct this review on a wider scale in the future. This paper was conducted as a systematic review of interventions on Statics courses and lectures. The question the review pursued is: What are the prevalent outcomes and patterns emerging from interventions aimed at enhancing student learning and experience in engineering Statics courses in higher education as evidenced in proceedings from previous annual ASEE conferences?

II. Literature review

The Role of Systematic Reviews

After a period of criticism about the lack of an organized critical summary of research in the field, “the worldwide Cochrane Collaboration was formed in 1992 to provide an expanding resource of updateable systematic reviews” (Grant, 2009, p. 92). This shows systematic reviews have their origins in the medical field. Gopalakrishnan (2013) further explained in the National Library of Medicine how a systematic review provides an objective summary of a wide array of information in the review’s respective field and in turn its highlight of gaps, successes, and points of note in the literature. By these definitions, a systematic review of any field can be useful in providing readers and future researchers with an objective, grounded point of reference to come back to or work from.

Conducting systematic reviews of course interventions is not a new concept. For example, Pitterson and Streveler’s (2016) systematic review conducted on Electrical Circuits course interventions relating to activities and learning environment. However, despite its significance as a foundational introductory course, Statics interventions did not seem to have had any form of a systematic review that we could find – and that was not because of a lack of publications. Due to the vital nature of the Statics course itself to education for future engineers, it was beneficial to prepare a systematic review, providing an objective summary of the current research landscape of Statics interventions.

Categorization of Course Intervention

The intervention categories we considered fall under a set of three intervention frameworks: Harackiewicz and Prinski (2018)'s motivational interventions, Donker et al. (2014)'s learning strategy interventions, and Borrego et al. (2013)'s practice and/or research-based instructional strategy (PRBIS) interventions.

Harackiewicz and Prinski (2018) revised and evaluated psychology-driven interventions presented two decades before its publication. It condensed the research landscape up until that point by labeling educational motivational interventions under three categories: task-value interventions, framing interventions, and personal values interventions. Then, contexts of motivational interventions were specified into three areas: course-specific, field-specific, and school-general. This helped us identify what category and context of interventions are based on if they were not clearly addressed.

The text additionally mentions contexts of motivational interventions that were difficult to categorize but listed as the subcategories "mitigating stereotype threat" and "changing attributions." Both fell under the general context with Blackmon and Hargrove-Leak (2022) being a good example that concentrates on intervening with student identity and diversity, equity, and inclusion (DEI). The authors described how these subcategories would need to be categorized properly in future revisions, but the idea is they heavily dictated a student's confidence and sense of belonging.

Summarizing this listing, we concluded with a motivational category list of intervention subcategories as follows: task-value interventions (e.g., utility-value, communal value), framing interventions (e.g., self-efficacy, belonging), personal value interventions (e.g., value affirmations), mitigating stereotype threat, and changing attributions, as shown in Table 1.

Donker et al (2014) conducted a meta-analysis on teaching strategies that help student metacognition and self-regulation to find which specific tactics worked best in improving student academic performance. The study reviewed 58 papers on interventions relating to enhancing student cognitive, metacognitive, and management strategy skills and how some relate to motivation. The study counted 95 interventions and condensed them into the three subcategories of cognitive (e.g., rehearsal, elaboration), metacognitive (e.g., planning, monitoring), and management (e.g., self-regulation) interventions. We extrapolated from this example relating to reading comprehension and critical thinking for the cognitive subcategory.

Borrego et al. (2013) discussed the third category of out interventions listed as Practice/Research-Based Instructional Strategy (PRBIS). The concept was commonly defined as "Any teaching approach supported by a statistical analysis of data from the learning

Table 1 *Motivational interventions sub-categories and concentrations*

Context	*Task value*	*Framing*	*Personal values*
Course specific *(e.g., engagement, interest, course grades)*	- Utility-value intervention	X	- Values affirmation intervention
Field specific *(e.g., course taking, interest in the field, career choices)*	- Communal utility-value intervention - Parent utility-value - intervention	- Social belonging intervention	X
School general *(e.g., enrollment rates, retention, overall GPA)*	X	-Attributional reframing - Mindset intervention - Difference education intervention - Social belonging intervention	- Values affirmation intervention

Note. Adapted from Figure 2, Harackiewicz & Prinski (2018, p. 417)

environment," (Apostolou et al., 2020, p.2). They systematically reviewed the state of PRBIS interventions, such as the quality, effectiveness, commonality, and encouraged their further implementation in engineering education. The full list of PRBIS included: Just-in-time teaching, case-based teaching, service learning, think-aloud-paired problem solving, inquiry learning, peer instruction, concept tests, think-pair-share, problem-based learning, collaborative learning, and cooperative learning. Using these as an example, many more practices and interventions can be considered PRBIS as well, such as like flipped classrooms, learning with technology, and discovery learning. Unlike previous frameworks, this category did not specifically define a subcategory to categorize PRBIS intervention examples further. For this reason, this framework's sub-category column was displayed as X.

The intervention frameworks we reviewed were simply to categorize various interventions in the STEM education research fields. These frameworks helped us identify where newly discovered and unlisted interventions lie with the existing frameworks.

III. Method

We followed Cochrane's (1995) guidelines for a systematic review, striving to discern, evaluate, and combine relevant empirical evidence that meets specific eligibility criteria established to address a defined research question. Using this, the literature was collected based on a set criterion, compiled into a database, summarized, and discussed. As one of the goals, the literature collected was summarized and sorted by an established coding scheme primarily focusing on intervention category and subcategory. Appendices A and B summarize our findings including a brief description of the intervention, outcomes, and results.

Data Analysis

Outliers and literature of note were discussed more thoroughly. The intervention literature's method was also considered when comparing results between qualitative, quantitative, and mixed method. Other considerations include the research sample size, study duration, study period, and whether it was affected by COVID-19. Study outcomes will be set in a binary scale of significance based on the research's own reported results. To clarify, the significance of the results was based entirely on the paper's own quantitative statistical calculations or the author's own qualitative conclusions – assumptions were not made unless clearly defined. We also highlighted the effects and significance of each intervention's outcomes as well as all the coding criteria mentioned to determine any trends or patterns that may exist. Each paper's assumptions and acknowledgments were considered when discussing the results' significance, as some may be affected by external factors, such as COVID-19 lockdowns.

Searching Strategies

The literature collected for this review was conference papers under the ASEE PEER website from 2013 to 2023. When a paper contains multiple studies, we distinguished them using study IDs to avoid any confusion. The main criterion for literature selection was that some form of intervention in a Statics course was conducted. This led to the expectation that these interventions would be conducted for up to 15 weeks. For further clarification, research simply testing a concept inventory or a new test item was not considered. The intervention needed to fall under any of the frameworks mentioned earlier – motivational, learning strategy, or PRBIS interventions.

Due to these restrictions, searching was done using the search keywords on ASEE Peer. Table 2 shows the search keyword results. Once searched, the results were filtered per year of publication to comb through the years 2013 to 2023. Each paper's abstract was used to determine whether it fit the selection criteria, and any unclear papers were read for certainty.

Inclusion and Exclusion Criteria

The main category for qualification for a review was any intervention paper explicitly stating the intervention was conducted on a Statics course. Literature that did not highlight an intervention or conduct its study on Statics were excluded. Literature that included other courses, such as Engineering Dynamics for parallel additional or longitudinal testing, was included as long as Statics is discussed equally or separately. Conference paper study periods were considered as the COVID-19 pandemic may have impacted the goals and results. Works in progress were rejected and repeated or overlapping studies will be combined into their respective latest revisions. The country of origin of a paper was not of much consideration unless it provided necessary context, or it did not follow the ABET standards. The majority of ASEE publications are from the U.S. or U.S. territory universities, and we did not exclude international literature if it fit the inclusion criteria.

As delineated in Figure 1, the articles were filtered by their titles, by their abstracts, and then by their content. Any papers that mentioned either Statics or interventions were selected to be further screened and read to determine their fit in relation to the inclusion and exclusion criteria mentioned earlier. Most backward citations of the included papers led to publications before 2013 – beyond the established publication date limit set for this review – in addition to works in progress, non-interventional papers, intervention studies conducted on courses that were not Statics, or previous iterations of the same study. The majority of studies found using the

Table 2 *Keyword searches and results on ASEE Peer*

Searched keywords	Results
Statics	6218
Statics + teaching	5534
Statics + teaching + introduction	3042
Statics + teaching + intervention	795
Statics + assessment + intervention	752
Statics + teaching + assessment + intervention	715
Statics + teaching + assessment + intervention + conclusion	358
Statics + intervention	773
Statics + inventory	693
Statics + class	5163
Statics + class + lecture	3253
Statics + mechanical engineering	5269
Statics + mechanical engineering + intervention	709

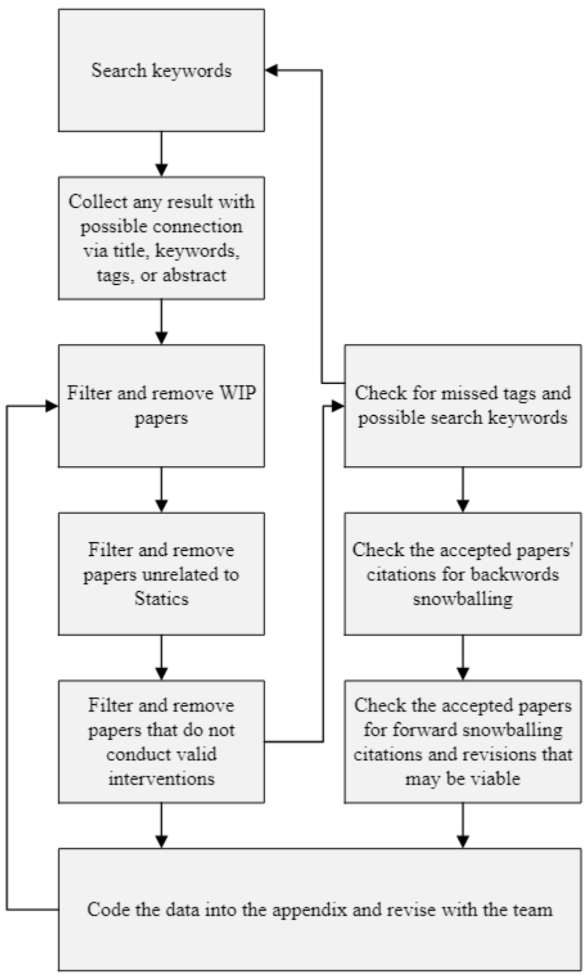

Figure 1 *Research searching, collecting, including, and excluding process flowchart*

backwards snowball method were therefore excluded from this paper, as they violated the established inclusion criteria. However, they could be considered for a future revision of this review with expanded limitations. As for citations that included previous iterations of studies with overlapping datasets, they have been compiled alongside their final iterations if the study met the required inclusion criteria. With that in mind, studies are distinguished from articles and papers as some publications described and analyzed multiple datasets, contained multiple research contexts, or comprised one part of the findings of a single multi-year study.

IV. Results

Appendices A and B present the compiled data of intervention articles found thus far within our research criteria. The appendices have been separated into two for ease of reading. Appendix A was assembled with the following columns: Authors, semesters of study, intervention category, intervention sub-category, intervention concentration, research intervention description, teaching method, summary of the outcomes, and reported significance of the results.

Appendix B was assembled with additional columns: Study ID, assessment method, study duration, study timeframe concerning COVID-19, research method, total sample size, test group sample size, and control group sample size. The authors column displays the reference author and publication date, both used to create the study ID codes for their respective papers. The research intervention description provides a brief introduction to what the research was about and what they were testing. The assessment method was meant to determine if the research was

Table 3 *Count of interventions used in studies per category and the percentage of articles per category reporting significant results*

Intervention category	Number of studies	Significance count (%)
Motivational	10	6 (67%)
Learning Strategy	6	3 (50%)
Practice-Based/RBIS	22	13 (62%)

Table 4 *Count of studies timed before, during, and after COVID-19 lockdowns vs their methodologies*

	Quantitative	Qualitative	Mixed	**Total studies**
Before covid	10	6	12	28
During covid	3	6	4	13
After covid	3	1	2	6
Total studies	16	13	18	47

Table 5 *Count of reported significance based on assessment method*

Reported significance using pre-post assessments	13
No reported significance using pre-post assessments	10
Reported significance using post-assessments	9
No reported significance using post-assessments	5

Table 6 *Count of interventions timed before, during, and after Covid-19 lockdowns vs their interventions*

COVID-19 status	Motivation	Learning strategy	PRBIS	**Total interventions**
Before	7	4	15	26
During	2	0	4	6
After	1	2	3	6
Total interventions	10	6	22	38

using assessments as a form of comparative data or not. Study duration was meant to cover whether the intervention was the entire 15 weeks (about 3 and a half months) of the semester, 10 weeks (about 2 and a half months), or any shorter duration. The sample sizes provided helpful references and possible research trends. Lastly, the papers' outcome and significance columns briefly discuss the conclusion results of the paper and intervention in question.

The most used category of interventions is PRBIS interventions with 22 studies followed by motivational interventions with 10 studies and learning strategy studies totaling 6 studies. The majority of the studies were said to be announced and conducted as a full semester intervention from start to finish with 15-week interventions making up 23 of the studies presented. 8 studies were conducted up to the second midterm or starting after the first midterms, at approximately 10 weeks. The remaining 6 studies were conducted during that time duration. Considering the recency of the COVID-19 pandemic, it makes sense that the majority of the studies were conducted before then at 29 studies. However, 13 were conducted during lockdown or were directly affected by the pandemic. 22 out of 37 publications reported significance in their results with the 23 publications also using pre-post assessment.

Despite having 37 research papers, some publications contributed additional data to the count. For example, our tally of intervention categories adds up to 38, as one paper included data and analysis of two different interventions within a single publication. Study duration did not change between different yearly revisions of studies, but some papers' studies were conducted during COVID-19 lockdowns. This resulted in the studies themselves being counted as conducted during the pandemic. Additionally, a few papers changed methods between revisions, but only one revision was considered complete enough to fit the inclusion criteria which is Jang and Taylor (2023).

One connection worth investigating is the significance of the results in relation to the category of intervention as shown in Table 4. One could argue that the only reason more PRBIS interventions reported significant results in comparison to other categories is due to their higher number of intervention use. This brings up another point, being the ease of application of PRBIS interventions. Following in this trend is Table 7 highlighting the preference researchers had regarding their choice of intervention before, during, and after lockdown. It displays their preference for PRBIS across all three time periods. The table also shows how learning strategies interventions were not conducted – and subsequently reported – during COVID-19. We suspect the difficulty of accurately gauging assessment results during lockdown contributed to this state of events.

Table 5's count of study methodologies against the number of studies conducted before, during, and after the COVID-19 pandemic does point toward a preference for qualitative studies during lockdown. This came as a surprise, as we had expected the results would lean more towards quantitative papers as the online forms of data acquisition would have made collection and analyzing submissions much easier – perhaps even automated. However, studying in lockdown and the requirement of online classes may have presented a rare opportunity to study student comfort and philosophy. Qualitative studies could provide deeper, more meaningful descriptive responses to the students' states at the time as well as in relation to the interventions. Overall, disregarding the timing, it appears that mixed methods was the most used research method for this subject of Statics interventions. Using both student assessment grades and student survey and interviews may provide a stronger research assessment outcome with multiple perspectives and a more triangulated result.

We propose there may be a possible correlation between the significance of a paper's results and its use of comparative pre-post assessment, or the study method chosen. This is the purpose of Table 6, which shows the reported significance or insignificance of study results using pre-post assessment methods. The greater number of pre-post assessments reporting significance and insignificance is chalked up to the fact there are more pre-post assessment studies on hand than not. Papers using only post-assessment do have less reported significance in their results than their pre-post counterparts in a ratio of 13 to 9, although this may only be a matter of coincidence.

V. Discussion

Appendices A and B present more than simple trends of studies. They also show interesting details about the way authors conduct an intervention. To begin this section, we discuss details that are missing from the tables. A recurring issue with most papers is the sample size. Thankfully, 35 out of 37 papers did mention or display their total sample size in some fashion. The only two not doing so are Talley et al. (2022) only mentioning the intervention testing was conducted on five different college campuses' Statics courses, and Blackmon & Hargrove-Leak (2022). It is unclear why they would not discuss their figures directly despite highlighting they received consent from both the campus departments and the students. However, these are only two of the 22 other papers that did not disclose their control group sample sizes. While it is not a requirement for studies to establish a control group, intervention research data can be made clearer and more valuable with comparative data analysis. To give them the benefit of the doubt, this may have been due to logistical issues of balancing scores between sections or classroom biases. This can also fall back on the intervention implementation not being comparative. However, the lack of a control group makes realistically interpreting the significance of implementation and the data difficult, especially in papers conducting only post-intervention assessment. Davishahl et al. (2020) solved their logistical issue by using previous and post intervention semesters as control group data. However, due to the nature of the post intervention semester being heavily affected by Covid-19, we neglect to count that as a study.

A noticeable amount of the motivational course interventions was targeting diversity, equity, and inclusion (DEI) and student sense of belonging. Each paper provides a different reason for their purpose, but their aim is consistently to improve student retention and help students not feel gatekept out of their major, such as in Perez et al. (2022). In addition, Tuchscherer (2018) conducted his DEI motivational intervention alongside a second PRBIS intervention.

PRBIS interventions are very clearly the majority favorite in this field of research according to Table 4's count. Most papers chalked their reasoning behind this up to Statics being a very traditionally taught course in most universities without much in the way of modern teaching tools and techniques. As a result, the course is fairly open to interventions that change the way a class is taught. Some can be smaller classroom intervention changes such as Dymond et al. (2023) presenting live examples for students to use as visual aids and to test their conceptual understanding of real-world examples. On the other hand, some changes can restructure the entire classroom dynamic while retaining the learning competencies, objectives, and outcomes such as Howard (2021) using both DELTA's classroom gamification model and flipped classroom interventions simultaneously. The flexibility of PRBIS interventions also allows for implementation regardless of classroom setting be it in-person, hybrid, synchronous, or even asynchronous.

Papers of interest

A few papers stood out to discuss their implementation, outcomes, methods, structure, or any other point of interest. Davishahl et al. (2022) introduced a more hands-on approach to learning using modeling tools in a flipped classroom setting. Their intervention was built on multiple previous non-interventional concept papers as well as a previously published work in progress. Despite the lack of significance in the results, they demonstrated that students enjoyed the change of pace as well as gained more experience using modeling tools. This is to show how the results' significance does not necessarily show the whole story and that the interventions conducted could be further tested for student motivation in the future.

Maalouf and Putzeys (2020) blended multiple interventions focusing on learning with technology and conducted a hybrid classroom before the pandemic lockdown. The paper was well structured and used a very consistent standardized language and presented every aspect of its work in detail explaining how they conducted their intervention and why. Their outcomes were similar to Davishahl et al. (2022) in the sense that despite its results lacking significance, the students' written and surveyed responses showed a preference for new changes in comparison to other previous traditional courses.

Goldberg et al. (2015) conducted a practice-based intervention focused on student reflection and self-regulation. Students found a use for this as a more personalized outlet for their concerns as well as visualizing their progress. As the paper concludes: "One unexpected finding was that some students said that they found the intervention useful because it gave them an unobtrusive means for asking a question, one that didn't draw attention to themselves or take up limited class time." (Goldberg et al., 2015, p.26). Even though this was not one of the expected or noted research goals, it is interesting to note students appreciate some form of private outlet for their questions outside of classrooms.

Finally, three papers we wanted to highlight are Myose et al. (2019), Myose et al. (2020), and Burkhart (2015). They all described studies conducted for six, eight, and eleven years respectively. Despite this, both Myose et al. (2019, 2020) showed a lack of any mention of a control group count while Burkhart (2015) highlighted that key aspect. Additionally, all three papers seem surprisingly short for papers conducting interventions with such a long sample size to draw conclusions and data. It may be that the data was so big that individual study highlights would have bloated the paper by the sheer amount.

Implications for research and practice

There are pointers we would like for future papers to be aware of from both this review as well as advice laid out in the reviewed literature itself. We start by discussing our own points from our observations in this review. First and foremost is the lack of a control group. Over half of the studies cited do not list a control group sample size for whatever reason. We believe that stronger research results are achieved through comparative research by defining a control group regardless of method. This can be done as a placebo test group section who will be informed to be in the test despite the lack of intervention. Understandably, some logistical issues may arise and not every intervention needs a control group, but research results can be considered more complete when assessed in multiple different ways including being weighed against non-intervention sections. A control group also puts into perspective student interest in intervention research.

Second, learning strategy interventions can be conducted more longitudinally. Aside from learning strategy interventions being the least conducted of the studies, it would help students adapt and learn to self-regulate even if not immediately within the Statics course itself. Checking in with students a semester or two later to measure the success of the taught learning strategies within the intervention can make for a good, repeated study not just for the sake of Statics but also for learning strategy research as a whole.

Regarding words of advice from the research, there are a few we want to highlight. One recurring theme among the papers is a limited sample size. This is especially evident in pilot studies as there is less of an established ground to work from. The perfect example is Walsh et al. (2017) directly citing the minimal sample size of seven students as one of the key issues affecting their work. Hopefully, future work can encourage more student participation to reduce this issue. This would especially benefit the results relating to student enjoyment of interventions and give them more merit such as Holdhusen (2015), Goldberg et al. (2015), and Davishahl et al. (2022). Larger sample sizes and more focus on student preference and engagement may help develop those interventions into more established teaching methods.

Blackmon and Hargrove-Leak (2022) pointed out from their experience that DEI interventions need a few factors to be more successfully effective. The paper concludes that meaningful DEI instruction in engineering education requires substantive, ongoing integration that contextualizes current events and evolves annually to reflect students' lived experiences and promote long-term relevance. Ruiz et al. (2021) adds to this by suggesting using DEI results from previous studies to implement course designs that help enhance student engagement in both interpersonal and societal levels. Perez et al. (2022) suggests that student awareness of the importance and implementation of DEI could help them pay more attention to it and help improve the classroom climate. Luthi et al. (2021) proposes diversifying samples further in any way. This includes other disciplines, other courses, and other institutions serving other demographics.

Implementation Proposal

Before we conclude, we want to propose a few ideas. Judging by the significant success of many interventions, we would like to point to some that should be considered as a permanent change for future Statics courses in general. For example, reflective practices such as the ones seen in Goldberg et al. (2015) and Goldberg et al. (2021) can provide healthy lifestyle changes to students that benefit them well in their student careers. The significance of the results mentioned is easy to assume and is only further established within the paper. We believe that implementing these interventions more regularly can provide easier communication between students and teachers and future testing can better show this in other courses as well.

Group work has shown mixed results and even the significant ones are not perfectly so, but this may be due to external factors. For example, Treadway et al. (2021) showed very promising potential and the pre-testing assessment predicted that. However, COVID-19 and the cascading events have created a poor space for group and project work. We believe a second attempt may benefit this study by knowing what we know now after seeing the results of papers such as Ande (2019). This can especially be made better when implementing learning-with-technology interventions such as Maalouf and Putzeys (2020) or more hands-on visual activities such as Atadero et al. (2014) that would further encourage teamwork and discussion. The choice of method only matters to the author as long as a form of comparison is made be it between control and test groups or with pre-post assessment for ease of understanding.

By the author’s subjective opinion and based on the results of this paper, we consider the following combined set of interventions to have a potentially significant impact on student comfort, confidence, understanding, and performance if implemented well. These are Howard (2021)’s gamification model, Jang and Taylor (2023)’s project and problem-based learning, Boylan-Ashraf et al. (2015)’s motivation of student self-efficacy can provide a drastically shifted tone to students. We believe that with enough effort, a coordinated balance can be worked to create a complete learning experience if introduced slowly over a few semesters.

Conclusions

The last decade of ASEE conference papers produced some interesting research findings for the interventions they used in Statistics. Traditionally taught courses like Statics provide a good control ground for interventions especially due to the wide range of student backgrounds that are mandated to take it. Positively successful interventions present possible changes in the future be it practice-based, motivational, or new learning strategies. Additionally, because of the wide range of students taking the course, DEI research does seem to be popular among motivational intervention papers. We hope our results and suggestions can set the stage for further improved Statics research intervention papers as well as improvements in the Statics course curricula in the near future.

References

References marked with an asterisk* indicate study is included in the review and table.

[1] *A. K. T. Howard, "Gamification design for engineering statics." *Proceedings of the 2021 ASEE Virtual Annual Conference Content Access*, Virtual Conference, Jul. 2021.

[2] *A. Mehdiabadi, R. A. Atadero, D. W. Baker, & A. M. A. Casper, "The effects of infusing diversity and inclusion into a design problem in engineering mechanics: Statics." *Proceedings of the 2019 ASEE Annual Conference & Exposition*, Tampa, Florida, 2019.

[3] A. S. Donker, H. De Boer, D. Kostons, C. D. Van Ewijk, & M. P. van der Werf, "Effectiveness of learning strategy instruction on academic performance: A meta-analysis." *Educational Research Review*, 11, pp. 1-26, 2014.

[4] B. F. Skinner, "The science of learning and the art of teaching." *Harvard Educational Review*, 24, pp. 86-97, 1954.

[5] B. J. Call, W. H. Goodridge, & T. L. Sweeten, "Spatial ability instrument ceiling effect and implications." *Proceedings of the 2016 ASEE Annual Conference & Exposition*, New Orleans, Louisiana, Jun. 2016.

[6] B. K. Sato, A. K. Lee, U. Alam, J. V. Dang, S. J. Dacanay, P. Morgado, G. Pirino, J. E. Brunner, L. A. Castillo, V. W. Chan, & J. H. Sandholtz, "What's in a prerequisite? A mixed-methods approach to identifying the impact of a prerequisite course." *CBE life sciences education*, 16(1), ar16, 2017. https://doi.org/10.1187/cbe.16-08-0260

[7] B. Z. Dymond, D. Ray, J. T. Hewes, J. Tingerthal, & R. Tuchscherer, "Board 40: Using "anchored instruction" to teach fundamental bridge engineering principles: A case study." *Proceedings of the 2023 ASEE Annual Conference & Exposition, Baltimore, Maryland*, Jun. 2023.

[8] *C. A. Halbmaier, S. Baxter, D. I. Humphrey, & B. Fralick, "A practical guide to graphical statics." *Proceedings of the 2016 ASEE Annual Conference & Exposition*, New Orleans, Louisiana, Jun. 2016.

[9] C. Papadopoulos, A. I. Santiago-Roman, M. J. Perez-Vargas, G. Portela-Gauthier, & W. C. Phanord, "Development of an alternative statics concept inventory usable as a pretest." *Proceedings of the 2016 ASEE Annual Conference & Exposition*, New Orleans, Louisiana, Jun. 2016.

[10] *C. Papadopoulos, "Changing the static: Insights and early results of a shift toward a studio-style statics class." *Proceedings of the 2023 ASEE Annual Conference & Exposition*, Baltimore, Maryland, Jun. 2023.

[11] *"Criteria for Accrediting Engineering Programs."* ABET.org https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2022-2023/ (accessed Feb. 27, 2024)

[12] *C. S. White, "Replacing graded homework assignments in statics." *Proceedings of the 2020 ASEE Virtual Annual Conference Content Access*, Virtual Online, Jun. 2020.

[13] *C. Venters, S. Goldberg, A. Masnick, K. Marks, & K. Panton, "Board 371: Relationships between metacognitive monitoring during exams and exam performance in engineering statics." *Proceedings of the 2023 ASEE Annual Conference & Exposition*, Baltimore, Maryland, Jun. 2023.

[14] *E. Davishahl, L. Singleton, T. Haskell, K. Rupe, L. Glen, "Scaffolding spatial abilities in integral calculus." *ASEE Annual Conference & Exposition*, 2022.

[15] *E. Davishahl, L. Singleton, T. R. Haskell, & K. M. Rupe, “Hands-on statics to improve conceptual understanding and representational competence.” *Proceedings of the the 129th American Society for Engineering Education Annual Conference and Exposition*, Minneapolis, Minnesota, USA, 2022.
[16] *E. Davishahl, T. Haskell, & L. W. Singleton, “Feel the force! An inquiry-based approach to teaching free-body diagrams for rigid-body analysis.” *Proceedings of the 2020 ASEE Virtual Annual Conference*, Jun. 2020.
[17] E. Davishahl, T. Haskell, J. Davishahl, L. Singleton, & W. H. Goodridge, “Do they understand your language? Access their fluency with vector representation.” *Proceedings of the 2020 ASEE Virtual Annual Conference*, 2019.
[18] E. L. Thorndike, “The contribution of psychology to education.” *Journal of Educational Psychology*, 1, pp. 5-12, 1910.
[19] *E. Treadway, J. E. Swenson, & A. W. Johnson, “Open-ended modeling group projects in introductory statics and dynamics courses.” *Proceedings of the 2021 ASEE Virtual Annual Conference Content Access, Virtual Conference*, Jul. 2021. https://doi.org/10.18260/1-2--37544
[20] G. Chauda, & G. Recktenwald, “Effect of a concept review intervention on the student’s knowledge retention and demonstration of pre-requisite fundamental concepts.” *Proceedings of the 2021 ASEE Virtual Annual Conference Content Access*, Virtual Conference, Jul. 2021.
[21] *I. G. Sorensen, D. Trageser, B. P. Self, & B. D. Lutz, “Using utility value interventions to explore student connections to engineering mechanics topics.” *Proceedings of the 2022 CoNECD (Collaborative Network for Engineering & Computing Diversity)*, New Orleans, Louisiana, Feb. 2022.
[22] *J. Burkhardt, “The effect of additional statics class time on at-risk student performance paper.” *Proceedings of the 2015 ASEE Annual Conference & Exposition*, Seattle, Washington, Jun. 2015.
[23] *J. Liao, G. Papkov, A. Badir, & R. O'Neill, “Assessment of precision, foundation, and knowledge in engineering mechanics.” *Proceedings of the 2022 ASEE Annual Conference & Exposition*, Minneapolis, MN, Aug. 2022.
[24] J. M. Harackiewicz & S. J. Priniski, “Improving student outcomes in higher education: The science of targeted intervention.” *Annual Review of Psychology*, 69(1), pp. 409–435, 2018. https://doi.org/10.1146/annurev-psych-122216-011725
[25] *J. Perez, F. Wachs, H. Nguyen, D. Miranda Barrios, L. Gossage, & B. Jones, “Supplemental instruction to decrease equity gaps in gate-keeper engineering courses (ERM).” *Proceedings of the 2022 ASEE Annual Conference & Exposition*, Minneapolis, MN, Aug. 2022.
[26] *J. R. Grohs, T. Kinoshita, B. J. Novoselich, & D. B. Knight, “Exploring learner engagement and achievement in large undergraduate engineering mechanics courses.” *Proceedings of the 2015 ASEE Annual Conference & Exposition*, Seattle, Washington, Jun. 2015.
[27] *K. A. Luthi, L. Macon, & M. Kar, “Peer-led team learning in introductory engineering courses: An analysis of an interventional method of support for underrepresented students at a two-year, Hispanic-serving public institution.” *Proceedings of the 2021 ASEE Virtual Annual Conference Content Access*, Virtual Conference, Jul. 2021. https://peer.asee.org/37572

[28] *K. J. Chew, H. L. Chen, B. Rieken, A. Turpin, & S. Sheppard, “Improving students’ learning in statics skills: Using homework and exam wrappers to strengthen self-regulated learning.” *Proceedings of the 2016 ASEE Annual Conference & Exposition*, New Orleans, Louisiana, Jun. 2016.

[29] *K. Luthi, M. Kar, & L. Macon, “Equity in engineering education: The experiences of non-traditional students in introductory engineering courses with peer learning support.” *Proceedings of the 2022 ASEE Annual Conference & Exposition*, MN, 2022.

[30] *K. Talley, J. Linsey, & J. Hurt, “Changing homework achievement with mechanix pedagogy: Increasing the efficacy of a measurement tool for construction majors.” *Proceedings of the 2022 ASEE Annual Conference & Exposition*, Minneapolis, MN, 2022.

[31] *L. L. Ruiz, D. Trageser, & B. D. Lutz, “Exploring student responses to utility-value interventions in engineering statics.” *Proceedings of the 2021 ASEE Virtual Annual Conference Content Access*, Virtual Conference, Jul. 2021.

[32] *L. S. Grundy & M. Koretsky, “Student metacognitive reflection on a conceptual statics question.” *Proceedings of the 2023 ASEE Annual Conference & Exposition,* Baltimore, Maryland, Jun. 2023.

[33] M. Borrego, S. Cutler, M. Prince, C. Henderson, & J. E. Froyd, “Fidelity of implementation of research-based instructional strategies (RBIS) in engineering science courses.” *Journal of Engineering Education*, 102(3), 394-425, 2013.

[34] *M. H. Holdhusen, “A flipped statics classroom.” *Proceedings of the 2015 ASEE Annual Conference & Exposition*, Seattle, Washington, Jun. 2015. https://doi.org/10.18260/p.23356

[35] *M. Villatoro, K. K. Peña, & J. Liou-Mark, “The effects of peer-led workshops in a statics course.” *Proceedings of the 2018 ASEE Mid-Atlantic Section Spring Conference*, Washington, District of Columbia, Apr. 2018.

[36] *N. Johnson-Glauch, & G. L. Herman, “Board 77: Visual representations guide students’ use of conceptual knowledge and problem-solving strategies.” *Proceedings of the 2019 ASEE Annual Conference & Exposition*, Tampa, Florida, Jun. 2019.

[37] O. Atilola, F. Vides, E. M. McTigue, J. S. Linsey, & T. A. Hammond, “Automatic identification of student misconceptions and errors for truss analysis.” *Proceedings of the 2012 ASEE Annual Conference & Exposition*, San Antonio, Texas, Jun. 2012.

[38] *P.C. Boylan-Ashraf, S.L. Billington, & S. Sheppard, “Using online and hands-on activities to improve self-efficacy in mechanics.” *Proceedings of the 2015 ASEE Annual Conference & Exposition*, Seattle, Washington, Jun. 2015.

[39] *R. A. Atadero, M. M. Balgopal, K. E. Rambo-Hernandez, & A. M. A. Casper, “Project-based learning in statics: Curriculum, student outcomes, and ongoing questions.” *Proceedings of the 2014 ASEE Annual Conference & Exposition*, Indianapolis, Indiana, Jun. 2014.

[40] *R. Barrage, G. W. Brodland, & R. Al-Hammoud, “Helping students to feel mechanics.” *Proceedings of the ASEE Annual Conference and Exposition, Conference Proceedings,* 2017.

[41] *R. Blackmon & S.C. Hargrove-Leak, “Course interventions to promote diversity, equity, and inclusion in engineering curricula paper.” *Proceedings of the 2022 CoNECD (Collaborative Network for Engineering & Computing Diversity),* New Orleans, Louisiana, Feb. 2022.

[42] R. K. Thornton & D. R. Sokoloff, "Assessing student learning of Newton's laws: The force and motion conceptual evaluation and the evaluation of active learning laboratory and lecture curricula." *American Journal of Physics*, 66(4), pp. 338-352, 1998. https://doi.org/10.1119/1.18863

[43] *R. Myose, L. S. Miller, & E. Rollins, "Student performance characteristics in a hybrid engineering statics course." *Proceedings of the 2019 ASEE Midwest Section Conference*, Wichita, KS, 2020.

[44] *R. Myose, S. Raza, E. Rollins, B. Buerge, & N. Smith, "Prerequisite testing as a tool to gauge incoming student capability and knowledge in an engineering statics course." *Proceedings of the 2019 ASEE Midwest Section Conference*, Wichita, KS, 2020.

[45] *R. Tuchscherer, C. A. Gray, & J. Tingerthal, "Examining interventions to increase classroom community and relevancy in an early career engineering course." *Proceedings of the ASEE Annual Conference proceedings*, 2018.

[46] *S. Ande, "Studying the effectiveness of peer instruction in statics." *Proceedings of the 2018 ASEE Gulf-Southwest Section Annual Meeting, AT&T Executive Education and Conference Center, Austin, TX* 78705, Apr. 2019.

[47] S. Baxter & B. Fralick, "Graphical statics redux paper." *Proceedings of the 2016 ASEE Annual Conference & Exposition*, New Orleans, Louisiana, Jun. 2016.

[48] S. C. Baxter, A. Johnson, & B. S. Fralick, "Revisiting graphical statics paper." *Proceedings of the 2015 ASEE Annual Conference & Exposition*, Seattle, Washington, Jun. 2015.

[49] S. Gopalakrishnan & P. Ganeshkumar, "Systematic reviews and meta-analysis: Understanding the best evidence in primary healthcare." *Journal of Family Medicine and Primary Care*, *2*(1), pp. 9–14, 2013. https://doi.org/10.4103/2249-4863.109934

[50] *S. Jang & C. Taylor, "Assessment of a final project of a large statics course on fostering creativity and inclusion." *Proceedings of the 2023 ASEE Annual Conference & Exposition*, Baltimore, Maryland, Jun. 2023.

[51] *S. Jang, "Redesign of a large statics course for neurodiverse students in the distance learning environment." *Proceedings of the 2021 ASEE Virtual Annual Conference Content Access*, Virtual Conference, Jul. 2021.

[52] *S. Jang, "Re-design of a large statics course to foster creativity and inclusion." *Proceedings of the 2022 ASEE Annual Conference & Exposition*, Minneapolis, MN, Aug. 2022.

[53] *S. R. Goldberg, C. Venters, & A. Masnick, "Refining a taxonomy for categorizing the quality of engineering student questions." *Proceedings of the 2021 ASEE Virtual Annual Conference Content Access, Virtual Conference*, 2021.

[54] *S. R. Goldberg, J. A. Rich, & A. M. Masnick, "Efficacy of a metacognitive writing-to-learn exercise in improving student understanding and performance in an engineering statics course." *Proceedings of the 2015 ASEE Annual Conference & Exposition*, 2015.

[55] *S. R. Maalouf & O. Putzeys, "Blended statics: Finding an effective mix of traditional and flipped classrooms in an engineering mechanics course." *Proceedings of the 2020 ASEE Virtual Annual Conference Content Access*, Virtual Online, Jun. 2020.

[56] S. Stevin, W. Hosch, T. Britannica, & Editors of Encyclopedia, "Statics." *Encyclopedia Britannica*. https://www.britannica.com/science/statics (accessed Sep. 18, 2019).

[57] *S. S. Condoor, B. MacGavin, & R. S. P. V., “Teaching the concept of tipping in statics: Pedagogy, practical examples, and potential activities.” *Proceedings of the 2023 ASEE Annual Conference & Exposition, Baltimore, Maryland*, Jun. 2023.

[58] *S. St. Clair, “Zone IV best paper: Assessment of long-term effects of technology use in the engineering classroom.” *Proceedings of the 2017 ASEE Annual Conference & Exposition*, Columbus, Ohio, Jun. 2017.

[59] S. Y. Yoon, P. K. Imbrie, T. Reed, & K. J. Shryock, “Identification of the engineering gateway subjects in the second-year engineering common curriculum.” *The International Journal of Engineering Education*, *35*(1), pp. 232-251, 2019.

[60] T. Sarker, D. C. Poleacovschi, D. M. Appelgate, D. K. Swalwell, D. C. Jackson, & D. K. Cetin, “Development of critical consciousness scale for civil engineering students.” *Proceedings of the ASEE North Midwest Section Annual Conference 2020*, 2020.

[61] V. K. Viswanathan, J. T. Hurt, T. A. Hammond, B. W. Caldwell, K. G. Talley, & J. S. Linsey, “Impact of a sketch-based tutoring system at multiple universities.” *Proceedings of the 2020 ASEE Virtual Annual Conference*, Jun. 2020.

[62] *Y. Walsh, A. J. Magana, T. Yuksel, V. Krs, I. B. Ngambeki, E. J. Berger, & B. Benes, “Board #39: Identifying affordances of physical manipulative tools for the design of visuo-haptic simulations.” *Proceedings of the 2017 ASEE Annual Conference & Exposition*, Columbus, Ohio, Jun. 2017.

[63] Y. Walsh & A. J. Magana, “Learning statics through physical manipulative tools and visuohaptic simulations: The effect of visual and haptic feedback.” *Electronics*, 12(7), 1659, 2023.

Appendix A: Descriptions of Interventions from 37 Articles

#	Authors	Category	Sub-category	Concentration	Description	TM	Outcomes	Sig
1	Ande (2019)	PRBIS	X	Think-pair-share peer group instruction	Students were informally paired together as teams to help supplement each other's learning through peer discussion	IC	Pre-post quiz scores showed 5-10% improvement. Two teams had students that needed extra help understanding concepts due to underwhelming communication.	Y
2	Atadero et al. (2014)	PRBIS	X	Project-based learning	Three group design project assignments were developed and implemented as a course intervention.	IC	The treatment group showed improved mastery of the topics. Modest positive impacts in project-based learning, proportional to course changes.	Y
3	Barrage et al. (2017)	PRBIS	X	Activity Kits	Learning activity kits were created to help students visualize and better understand Statics concepts and dispel misconceptions through experience	IC	Survey shows hands-on activities with physical models to help students understand core mechanics, build intuition, and clear misconceptions	Y
4	Blackmon & Hargrove-Leak (2022)	M	Framing and Mitigating stereotype threat	DEI and belonging	Course time is taken to emphasize the importance of DEI in engineering perspectives and design.	IC	DEI perceptions in the program improved noticeably, but further improvement is still possible	Y
5	Boylan-Ashraf et al. (2015)	M	Framing	Self-efficacy	Student self-efficacy is measured after instilling hands-on activities throughout the course and compared between a variety of backgrounds.	HY	Active learning and strategic online activities enhance student self-efficacy and contribute to growth.	Y
6	Burkhart (2015)	PRBIS	X	Additional contact time	Additional hour of class time per week was given to lower performing students	IC	Improvements in the common final exams and final course grades were minor and not statistically significant.	N
7	Chew et al. (2016)	M	Metacognitive	Reflection	Reflection surveys are conducted to check student confidence and self-regulation after homework and tests	IC	Wrappers impact engineering statics learning, boosting confidence and reducing assignment mistakes, positively affecting student performance.	Y
8	Condoor (2023)	PRBIS	X	Problem/case-based learning	Introducing the topic of tipping in Statics using tasks designed for the classroom to test student understanding of subtopics before and after the lesson	IC	Results indicate a notable rise in footprint-related responses post-intervention, suggesting improved understanding and implementation of the concept by participants.	Y
9	Davishahl et al. (2020)	Motivational	Task-value interventions	Inquiry-based learning model	Teaching students free-body diagram interpretations and concepts using more real-world inquiry-based learning activities inspired by POGIL	IC	Students embraced this approach better than relying solely on heuristics with improved (but not significant) performance on final exams	N

10	Davishahl et al. (2022)	PRBIS	X	Hands-on Modeling Curriculum	Students would use hands-on modeling tools to communicate their understanding in a flipped classroom.	S	Intervention students showed slightly higher conceptual gains and gave positive feedback, though not statistically significant due to small sample.	N
11	Goldberg et al. (2015)	LS	Metacognitive	Writing prompt	A writing prompt is implemented to one prompt in every HW assignment for 10 assignments total to check student metacognition	IC	The intervention semesters showed a statistically significant increase in final exam scores and general self-reported exam preparation time	Y
12	Goldberg et al. (2021)	LSv	Metacognitive	Self-reflection	Students are prompted to ask questions and use a taxonomy list to learn to ask better questions	IC	There is confidence in the significance of task success in modified question classification taxonomy effectiveness for students.	Y
13	Grohs et al. (2015)	LS	Metacognitive	Self-regulation	Students are encouraged to self-regulate and motivate themselves through self-reflection surveys	HY	It created a negative feedback loop: Less successful students doubled down on poor strategies, while already more successful students enhanced their strategies	N
14	Grundy & Koretsky (2023)	LS	Metacognitive	Response monitoring	A variety of comparisons made between student responses to a conceptual Statics problem	IC	There is no significant connection between answer connection and student confidence nor is there between student confidence and their institution.	N
15	Holdhusen (2015)	PRBIS	X	Flipped classrooms	The concept of a flipped classroom is tested in a Statics course to compare student score difference	AS	The average is only a 0.1 GPA score higher which is not statistically significant, but student survey favored the new format.	N
16	Howard (2021)	PRBIS	X	DELTA gamification and flipped classroom	Testing the adoption of DELTA's gamification module in a Statics classroom setting along with input from non-engineers of varying backgrounds	HY	Input from non-engineers can improve any review, students are more satisfied working with younger individuals, and effective communication with graphic designers requires a shared language.	Y
17	Jang & Taylor (2023)	PRBIS	X	Open-ended final projects	Open-ended creatively driven projects and problem-solving statements were introduced as a creative alternative assessment instead of a final exam	HY	Both project tracks scored higher (91.7) than the final exam (80.35). Open-ended projects show higher creativity ratings, but more variability compared to problem-solving projects.	Y
18	Johnson-Glauch & Herman (2019)	PRBIS	X	Visual representations	Students with limited spatial skills are engaged with new visual representations in problem-solving tasks.	IC	Context influences knowledge application in engineering education, which aligns with other studies highlighting context-dependence in students' understanding.	Y

19	Liao et al. (2023)	M	Framing interventions	Confidence and self-efficacy	Testing is done to find consistencies between instructor assessment and student perception of deficiencies.	IC	Exam errors varied with knowledge cited for loss, instructor-student disagreements on assessments occurred, and confidence does not significantly play a role in student success.	N
20	Luthi et al. (2022)	PRBIS	X	PLTL	Attempting to present one aspect of the effects of PLTL qualitatively	IC	Overall success is noted in the results with gender creating most of the diversity in results	Y
21	Luthi et al. (2021)	PRBIS	X	PLTL	Attempting to present one aspect of the effects of PLTL quantitatively	IC	PLTL helped improve minority students' overall representation and sense of belonging which is further supported by the student survey results.	Y
22	Maalouf & Putzeys (2020)	PRBIS	X	Blended learning methods	A variety of interventions including blended format, the use of a "lightboard", recording minilecture videos, flipping a certain number of classes, introducing active learning, and more use of online resources.	IC	Student feedback suggests the overall effectiveness of the blended format. While there is no clear stand-out advantage emerged, students enjoyed and preferred it, citing benefits in teamwork and practical skills.	Y
23	Mehdiabadi et al. (2019)	M	Mitigating stereotype threat	DEI	An interventional assignment to improve student assumptions about DEI, perspective, and problem-solving.	IC	Participation in group problem-solving at the end of the course enabled students to identify assumptions, allowing the intervention to challenge and dispel them.	Y
24	Myose et al. (2019)	PRBIS	X	Hybrid classroom	The paper assessed the success of hybrid classroom teaching in Statics	HY	While semester averages remained steady, score distribution changed notably, with decreasing variance among grade levels over time.	N
25	Myose et al. (2020)	M	Framing	Performance prediction	Pre-requisite testing is conducted to predict student GPA performance	IC	Pretest results were moderately successful at predicting student course cumulative grades.	Y
26	Papadopoulos (2023)	PRBIS	X	Studio format of education	Classes are conducted in a mix of lab tasks and studio lectures.	IC	Results indicate improved student performance and significantly improved student interest and engagement.	Y
27	Perez et al. (2022)	M	Mitigating stereotype threat	DEI	Teachers try to raise students' sense of belonging using Technology Assisted Supplemental Instruction (TASI)	SY	TASI is a helpful institution-provided resource for struggling students and URM students that lack a sense of belonging which resulted in less gatekeeping and more retention.	Y
28	Ruiz et al. (2021)	M	Task-value	Utility-value	A look into student responses to the UVI and its effect on student racial and gender relations	SY	Linking values to course content helps engineering students find personal significance, fostering resilience and motivation for academic success.	N

29	Sorensen et al. (2022)	M	Task-value interventions	Utility-value interventions	Course delivery includes relating course content and concepts with student experiences	SY	Students would relate mechanics concepts to current/future goals, real-life relevance, and societal impact in engineering awareness.	Y
30	St. Clair (2017)	PRBIS	X	Technology-enhanced learning	The paper attempts to find correlation between information retention and computer use in comparison to group learning.	IC	All groups performed equally on the assessments, challenging the expectation that instructional technology enhances retention since in-class activities proved equally effective.	N
31	Talley et al (2022)	PRBIS	X	Technology-enhanced learning	Sketch recognition technology is used as an automated grading software for online homework submissions	SY	Engineering majors showed score increases, but not statistically significant. Low student motivation possibly due to Covid impacted the results.	N
32	Treadway et al. (2021)	PRBIS	X	Open-ended modeling problem	Discovering the effects of implementing an open-ended ill-defined modeling analysis problem assignment in both Statics and Dynamics courses	IC	Attitudes towards the format were leaning more negative possibly due to communication issues, COVID-19, expectations, lack of choice, and/or final project formatting	N
33	Tuchscherer (2018)	M & PRBIS	Mitigating stereotype threat, Personal value interventions	Classroom climate, Framing, Peer-led instruction, and Problem/case-based learning	A variety of smaller interventions are tested to foster an engineering community.	IC	Identity, community, and self-efficacy scores all increased, but with no statistical significance between TG and CG.	N
34	Venters et al. (2023)	LS	Metacognitive	Monitoring	Student metacognitive calibration is tested using additional support practices and score prediction with their overall performance being considered.	IC	No significant increase in student performance when compared to overall trends. However, score predictions were accurate.	N
35	Villatoro et al. (2018)	PRBIS	X	PLTL instructional design	Sections were divided based on peer-led team learning and grades were compared.	IC	Passing rates for PLTL sections were almost 20% higher than other sections with 10% lower withdrawal rates.	Y
36	Walsh et al. (2017)	PRBIS	X	Computer simulation learning tools	Physical Manipulative Tools is used to test how successful it is at teaching statics concepts.	IC	Small sample size was not enough to show significance, but results were encouraging for further testing.	N
37	White (2020)	PRBIS	X	Worked Examples	Homework questions were used in quizzes and quiz grades were used as a tracker of the ongoing learning.	IC	Students that put in further effort to solve the homework in preparation for the quizzes yielded numerical advantage over simply studying quiz solutions.	Y

Note. LS = Learning strategy; M = Motivational; PRBIS = Practice-Based RBIS; PLTL = peer-led team learning; TM = Teaching method, IC = in-class, HY = Hybrid, SY = Synchronous, AS = Asynchronous; Sig = Reported significance, Y = Yes, N = No

Appendix 2: Research Design of 47 Studies

#	Study ID	Semester	Assessment	Duration (weeks)	COVID-19	Method	N_T	N_{TG}	N_{CG}
1	And1901	N/R	PrePst	10	B	Quan	14	14	N/R
2	Ata1401	F12	PrePst	15	B	Mixed	209	101	108
3	Bar1701	N/R	PrePst	10	B	Qual	46	46	N/R
4	Bla2201	F18	Pst	15	B	Mixed	N/R	N/R	N/R
	Bla2202	F19	Pst	15	B	Mixed			
	Bla2203	F20	Pst	15	D	Mixed			
5	Boy1501	F14	PrePst	10	B	Mixed	79	79	N/R
6	Bur1501	F00 to F11	Pst	15	B	Quan	493	407	86
7	Che1601	F15	PrePst	6	B	Mixed	70	70	N/R
8	Con2301	N/R	PrePst	4	A	Quan	31	31	N/R
9	Dav2001	W18, F19, W20	Pst	8	B	Qual	39	14	25
10	Dav2201	F20, W21	PrePst	5	D	Quan	27	16	11
11	Gol1501	F14, S15	PrePst	15	B	Mixed	106	66	40
12	Gol2101	F19	Pst	10	B	Qual	35	35	N/R
13	Gro1501	F14	PrePst	15	B	Quan	340	151	189
14	Gru2301	N/R	PrePst	8	A	Mixed	241	241	N/R
15	Hol1501	F13, S14	Pst	15	B	Mixed	75	22	53
16	How2101	F19	PrePst	15	B	Mixed	480	480	N/R
	How2102	S20	PrePst	15	D	Mixed			
17	Jang2301	F20, S21, F21	Pst	15	D	Quan	442	193	249
	Jang2101	F20	Pst	15	D	Mixed	166	91	75
	Jang2201	F20	Pst	15	D	Qual	155	74	81
	Jang2202	S21	Pst	15	D	Qual	171	90	81
	Jang2203	F21	Pst	15	D	Qual	136	55	81
18	JoGl1901	N/R	Pst	15	B	Qual	15	15	N/R
19	Liao2301	F21	Pst	15	A	Quan	63	63	N/R
20	Lut2201	Su18 to S20	Pst	15	A	Qual	518	518	N/R
21	Lut2101	Su18 to S20	PrePst	15	B	Quan	518	518	N/R
22	Maa2001	S18, F18, S19	Pst	15	B	Mixed	127	21	106
23	Meh1901	S18	PrePst	10	B	Qual	76	76	N/R
24	Myo1901	S12 to F18	PrePst	15	B	Quan	343	343	N/R
25	Myo2001	S10 to S18	PrePst	15	B	Quan	350	350	N/R
26	Pap2301	F22	Pst	15	A	Mixed	48	N/R	N/R
27	Per2201	S19, F19	PrePst	15	B	Quan	762	264	498
	Per2202	S20, F20, S21	PrePst	15	D	Quan			
28	Ruiz2101	F20	Pst	15	D	Qual	101	101	N/R
29	Sor2201	F20, W21	PrePst	15	D	Qual	101	44	57
30	StCl1701	N/R	PrePst	15	B	Quan	267	152	115
31	Tall2201	F19, S20, F20, S21	PrePst	5	D	Mixed	5U	N/R	N/R
32	Tre2101	S20	PrePst	15	D	Qual	45	20	N/R
33	Tuc1801	S17	PrePst	10	B	Mixed	119	53	66
	Tuc1802	F17			B	Mixed	136	66	70
	Tuc1803	S18			B	Mixed	152	92	60
34	Ven2301	F21, S22, F22	PrePst	15	A	Quan	70	70	N/R
35	Vill1801	S09 to F16	Pst	10	B	Quan	1396	999	397
36	Wal1701	S17	PrePst	15	B	Qual	7	7	N/R
37	Whi2001	F19	Pst	10	B	Quan	33	33	N/R

Note. Semester: S = spring, Su = summer, F = fall, W = winter; PrePst = pre-post assessments, Pst = post-assessments; N_T = total sample size; N_{TG} = treatment group sample size; N_{CG} = control group sample size; COVID-19: B = before, D = during, A = after