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Teaching and Learning Hooke's Law Using Physical, Interactive Software and Blended Approach: An Overview

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Abstract

At present, with technological advancement and changes in students' preferences, there are both challenges and opportunities to enhance the teaching and learning of subjects in science, technology, engineering, and mathematics (STEM). In this article, we explore reported works in established databases on the topic of Hooke's Law, to see the approaches used in teaching and learning of the topic. Searches were performed in Web of Science, Scopus and Google Scholar databases, after which manual filtering for relevant articles was carried out by reading and browsing through the abstracts. Based on the types of works, the articles were separated into three parts: physical, interactive software, and blended. In total, 21 relevant articles were reviewed. The data obtained can be separated into three categories: physical, interactive software, and blended. Of the three, blended approaches were used the least. To further explore the topics discussed in the articles related to Hooke's Law, a bibliometric study was performed. From the results, we found that, with the advantages offered by the blended approach, and none using artificial intelligence, there is still room for improvement to enhance the teaching of Hooke's Law, specifically, and generally, on introductory physics subjects.

Keywords: Hooke's Law, introductory physics, STEM, teaching and learning.

INTRODUCTION

Maintaining a consistent output of students in STEM subjects is becoming more challenging due to a decline in student interest across all STEM disciplines over the last few years. This decrease in enrollment reflects a waning enthusiasm for these subjects, and many factors contribute to this trend (Mulvey, Cerda-Smith, Joy, Mathews, & Ozturk, 2023; Saha, Islam, Akhi, & Saha, 2024). Generally, the factors include, but are not limited to, difficulty in understanding abstract concepts, lack of interest and motivation among students, poor mathematical skills, and limited access to laboratory equipment. Traditional teaching methods often fall short in fostering deep conceptual understanding, leading to students' difficulty in applying knowledge to new contexts.

Physics courses are not exempt from the challenges mentioned above. As one of the most fascinating subjects within STEM, physics allows students to explore both visible and invisible phenomena, as well as intangible concepts. Studying physics involves understanding our surroundings, predicting outcomes, and potentially creating innovations. Physics often involves abstract concepts that can be challenging for students to grasp without proper visualization and practical examples. Teaching is a profession that involves skills to convince the listeners. There are several examples of using technology in teaching physics that can enhance the learning experience and help students grasp complex concepts more effectively. Some of these technologies include simulations and interactive software, virtual labs, a flipped classroom, and problem-based learning (PBL). These technologies and approaches can significantly enhance the teaching and learning of physics by making the subject more engaging and accessible to students. From experience in teaching physics, many students struggle with physics due to a weak foundation in mathematics, which is essential for understanding and solving physics problems, and this is where most students dread the most.

There has been no unified approach in teaching and learning physics on the classic topics. Students have the notion that there are a vast number of online resources that can self-study, but websites are not permanent (Bar-Ilan & Peritz, 2009; Oguz & Koehler, 2016) and the contents might not be verified. Unverified contents are just opinions or comments without scientific proof to back them up. In general, with the availability of the internet and electronic gadgets, everyone can self-learn through media social like YouTube or TikTok. But without the guidance of a teacher, possibly a lot of time will be spent finding the right materials. Moreover, a teacher is also important in pointing out the essentials of a topic, thus enhancing the learning experience difficult to obtain from self-learning. For physics, the source of learning online is not plentiful. The famous ones being PhET, YouTube and TikTok channels. On the surface, the existence of a YouTube channel or TikTok is another platform for self-learning, however, upon further scrutiny, it might not help as hoped, as students might not be paying attention during classes, due to the notion that they can be self-sufficient through those social media channels. Lackadaisical behaviour may arise from this, and this situation kills the enthusiasm of a teacher.

In this article, we focused on approaches used in teaching and learning of Hooke's Law. Hooke's Law is a topic in an introductory physics course. Hooke's Law is defined as "elongation is proportional to the force applied, as long as it is in the linear region". This law can be represented with a plot of force (F) versus extension of the material (x). Textbook materials do highlight the definition of laws, but there are no teaching methods involved. To attract the attention of students, apart from oratory skills, creativity in using the materials in teaching can be another approach. With the advancement of software and hardware, it is useful to illustrate the current approaches in teaching this topic. However, there have been no studies on the use of technology in teaching and learning of Hooke's Law. Hence, the idea in this work is to obtain a big picture in engaging students based on technology (e.g., apps and simulations). The argument is that, if the motivations of the students can be preserved or enhanced in the basic physics, they will continue to be interested in learning more about physics and produce more students in STEM. Thus, this work can be considered a preliminary, surface-level examination of the integration of technology by educators in introductory physics.

METHOD

To achieve the objective, we used the advanced search features to find the term "Hooke's Law" in the title and abstracts, in the Web of Science (WoS) and Scopus databases. Those found in the WoS and Scopus are peer-reviewed and indexed by the respective databases, hence their inclusion in this study. Hits from Google Scholar are also included here to identify sources that are not indexed.

The search strategy in WoS is as follows: TI="Hooke's Law" and TS="Hooke's Law" for finding Hooke's Law in title and topic, while in Scopus, the search was using TITLE-ABS-KEY ("Hooke's Law" AND (teach OR study OR learn)) AND (LIMIT-TO (SUBJAREA, "PHYS") OR LIMIT-TO (SUBJAREA, "MULT") OR LIMIT-TO (SUBJAREA, "BUSI") OR LIMIT-TO (SUBJAREA, "ENER") OR LIMIT-TO (SUBJAREA, "COMP")). The search in WoS returned 73 hits. As for Scopus, the advanced search returned 58 hits in relevant areas. The articles are filtered based on relevancy in the title and abstract. An article will be included if it is on the teaching and learning of Hooke's Law. If an article is on using Hooke's Law in explaining certain phenomena or for advanced studies (for example, the works of Bogdan et al., (2023), Yuan et al., (2022), and Zhao & Sun (2025)), then it will be excluded. Upon filtering, only 7 from WoS and 13 from Scopus were relevant for our discussion. From Google Scholar, as enormous data is returned from the search with limited search options, the best effort of screening through the hits returned six related studies, using the search strings "learning, OR study, OR teaching "Hooke's Law". In total, we have 21 publications on teaching and learning Hooke's Law. The procedures are summarized in Figure 1, based on the PRISMA flow diagram (Page et al., 2021).

From the obtained data, we manually separated the works into "physical", "interactive software", and "blended". The idea for the separation is to get a clearer picture of the current state of teaching and learning of Hooke's Law. Figure 2 shows the separation of the works.

To further evaluate the studies that have been performed on and using Hooke's Law, a bibliometric analysis was performed. The data we used are from Wos. As the difference in choosing Scopus or WoS is negligible (Archambault, Campbell, Gingras, & Larivière, 2009), using WoS for a bibliometric study was purely a choice of convenience.

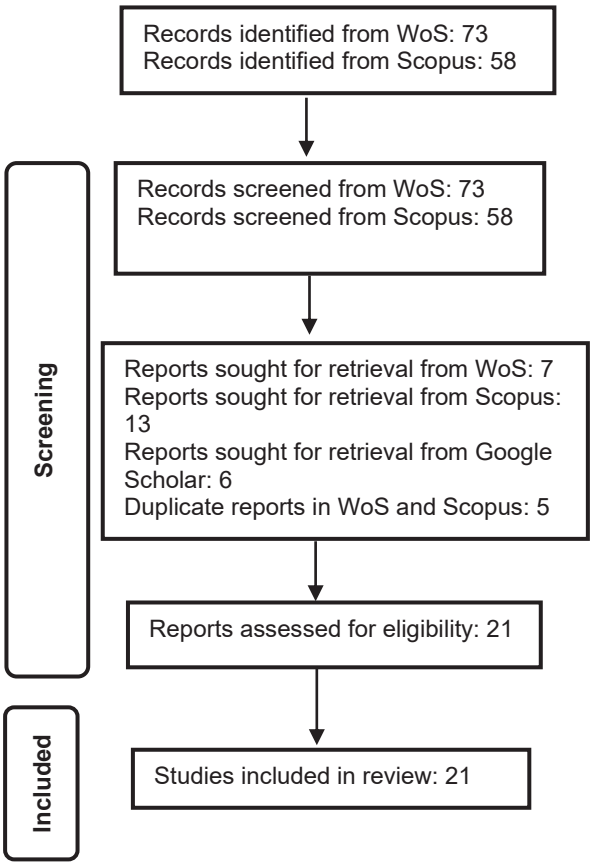


Figure 1. The PRISMA flow diagram depicts the procedures taken for this study

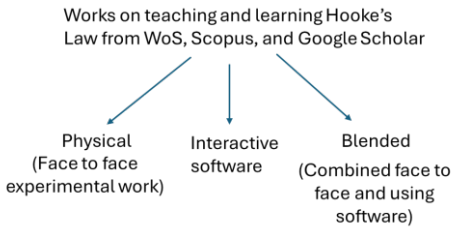


Figure 2. Three types of works were retrieved from the three databases of WoS, Scopus, and Google Scholar

RESULT AND DISCUSSION

For each of the studies, we provided a summary of the work performed. Table 1 shows

the relevant works. Of the 21 studies in Table 1, 9 are from physical, 10 from interactive software, and two from blended. Based on Table 1, common among physical studies of Hooke's Law is to find the spring constant using electronics (remote or Arduino) and to introduce the concept of linearity of the spring. Hooke's Law is also used to relate to simple harmonic motion and elastic energy. Further search in the databases found that there are more uses of Hooke's Law: it has been used to explain molecular behaviour and forces (e.g. infrared spectroscopy (Wright & Oliver-Hoyo, 2019) and molecular dynamics (Lamberti, Fosdick, Jessup, & Schauble, 2002)). Thus, understanding and applying Hooke's Law in other science subjects can lead to the appreciation of the law.

Table 1. Works on teaching and learning of Hooke's Law in WoS- and Scopus-indexed journals, and Google Scholar. The title with superscript # is indexed in WoS, superscript @ in Scopus, and superscript * in Google Scholar

Types of work	Title and works performed
Physical	A more efficient approach to demonstrate Hooke's Law (Wei & Chong, 2022)[#@] In this work, the authors present an efficient and intuitive approach to demonstrate Hooke's Law.
Physical	Didactic press for remote experimentation applied in spring to study Hooke's Law (Michels et al., 2013)[#@] In this work, the authors introduced a remote experiment designed to facilitate the observation and study of Hooke's Law, allowing students to access the experimental setup at any time of the day. Students experiment remotely by logging in through a webpage.
Physical	IR spectroscopy or "Hooke's Law at the molecular level" – A joint freshman physics-chemistry experience (Burke, 1997)[#] The author reports on understanding IR spectroscopy after the students were taught on the topic of Hooke's Law, in the hope of having a better understanding of molecular vibrations.
Interactive software	Development of physics learning media based on Lectora Inspire Software on the elasticity and Hooke's Law material in senior high school (Kurniawan, Mujasam, Yusuf, & Widyaningsih, 2019)[#@] The authors developed physics learning media using Lectora Inspire software, focusing on elasticity and Hooke's Law, to enhance the physics learning process for high school students.
Interactive software	PASSING for the experiment tool in elasticity and Hooke's Law concept on springs arranged in series and parallel (Suhendi, Nurhasanah, Yuningsih, Mulhayatiah, & Malik, 2019)[#@] The authors assessed the use of the PASSING development tool to create learning media to study elasticity and Hooke's Law and found it to be feasible.
Physical	Illustrating dimensionless scaling with Hooke's Law (Bissell, Ali, & Postle, 2022)[@] Using Hooke's Law to illustrate dimensionless scaling provides an opportunity for students to understand the concept of dimensionless scaling.
Physical	Determination of spring constant by Hooke's Law and simple harmonic motion experiment (Wulandari, Iswanto, & Sugihartono, 2021)[@] Comparing the methods of Hooke's Law and SHM to find the spring constant should be discussed after SHM is taught.
Physical*	Determining the spring constant using Arduino (Çoban & Çoban, 2020)[@] Determine the constant spring using electronic devices, an experiment with twenty-first-century skills.
Physical	Hooke's Law experiment using an electronic speckle pattern interferometry (Park & Huh, 2020)[#@] To study the bending of a cantilever beam. The deformation is measured using an electronic speckle pattern interferometer.
Interactive software	The development of student worksheets with PhET assisted in improving student science process skills (Arifullah, Halim, Syukri, & Nurfadilla, 2020)[@] Develop worksheets in Hooke's Law, and carry out Hooke's Law using PhET, as to improve the science skills, measured using seven indicators.
Interactive software	The development of multi-representation practicum modules with PhET on Hooke's Law concept (Mizayanti, Halim, Safitri, & Nurfadilla, 2020)[@] Using PhET and developing multi-representation modules received positive responses.
Physical	Hooke's Law and the non-linear springs, a study of a case (Aranha, Jr, Bellio, & Jr, 2016)[@] It is a comparative study of different materials, on the linear and non-linear behaviour, and the need to fit the experimental data with equations.
Physical	Studying springs in series using a single spring (Serna & Joshi, 2011)[@]

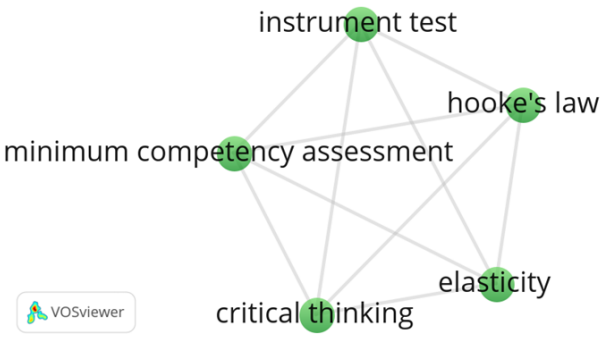
Types of work	Title and works performed
	This work explores the seldom-discussed combination of several springs to verify Hooke's Law.
Interactive software	Development of STEM model student worksheets with PhET simulation on Hooke's Law material to improve the ability students' critical thinking (Agustina & Dwikoranto, 2021)[@] This research aims to describe the feasibility of STEM model student worksheets in guided inquiry learning with PhET Simulation media on Hooke's Law material in terms of validity, effectiveness and practicality.
Interactive software	Development of an electronic physics learning module with PhET (physical education and technology) simulation on elasticity and Hooke's Law in class XI senior high school (Rahma, Rustana, & Umiatin, 2021)[*] This article describes the results of the development of an electronic module for learning physics about elasticity and Hooke's Law in class.
Interactive software	The Integrating STEM in Hooke's Law and Elasticity Worksheets: Enhancing Student Collaboration and Learning Outcomes(Rasmi, Wibisana, & Hendri, 2025)[*] This study aims to determine the effect of web-based worksheets based on STEM-integrated problems on students' collaboration skills. The authors concluded that the STEM-integrated physics web worksheet on the Elasticity and Hooke's Law material can improve students' collaboration skills.
Interactive software	The Effect of STEAM-Based Project-Based Learning Model on the Critical Thinking Skills of Eleventh-Grade Students in the Topics of Elasticity and Hooke's Law (Hasani, Ardhuha, Harjono, & Kosim, 2024)[*] This study aims to examine the effect of the Project-Based Learning (PBL) model based on STEAM on students' physics critical thinking skills using elasticity as the topic. Based on the analysis results, it can be concluded that there is an effect of the Project-Based Learning model on students' physics critical thinking skills.
Interactive software	Development of Critical Thinking Instrument with Minimum Competency Assessment Characters on Elasticity and Hooke's Law (Ningsih, Susanti, Serevina, & Maulana, 2024)[#] This study aims to develop an instrument test to measure critical skills that students have which are followed by the minimum competency assessment for elasticity and Hooke's Law high secondary level. However, no concrete conclusion is offered in the article.
Blended	Enhancing Problem-Solving Skills in Elasticity and Hooke's Law through Problem-Based Learning with PhET Media and Mechanics Kits (Niko, Odja, & Payu, 2024)**[*]** This research aims to determine the influence of the Problem-Based Learning model assisted by PhET media and Mechanics Kit on problem-solving ability in elasticity and Hooke's Law. The authors concluded that it has significant influence of applying the Problem-Based Learning model assisted by PhET media and Mechanics Kit on problem-solving abilities in elasticity and Hooke's Law.
Blended	The Influence of the Problem-Based Learning Model Assisted by Video-Based Laboratory on Students' Ability to Solve Problems on Elasticity and Hooke's Law (Yunus, Odja, & Buhungo, 2024)[*] This study aims to determine the significant effect of the problem-based learning model assisted by video-based laboratory on students' problem-solving abilities in improving problem-solving abilities on the material of elasticity and Hooke's Law. The results show that the application of the problem-based learning model in the form of a video-based laboratory had a significant effect on students' problem-solving abilities on the material of elasticity and Hooke's Law.
Interactive software	Efektivitas Media Pembelajaran Simulasi PhET terhadap Kemampuan Literasi Digital dan Hasil Belajar Siswa pada Materi Elastisitas dan Hukum Hooke (Koilmo, Hali, & Kameo, 2025)[*] The purpose of this study was to determine the effectiveness of PhET simulation virtual lab learning media on digital literacy skills and student learning outcomes. Based on data analysis, it is said that the use of PhET simulation virtual lab learning media is effective in improving digital literacy skills and student learning outcomes.

As for the interactive software approach, it is to create learning media by using software. Software used includes Lectora Inspire, PASSING, or using PhET. One conspicuous omission among the studies on interactive software approach is the lack of a link to access the software created, hence it is difficult to compare the efficiencies of physical and the method using interactive software. Thus, the use of interactive software can be seen as providing alternatives to the physical approach. Furthermore, physical and interactive software approach have their own advantages. Combining them is another alternative. Two blended approach studies are included in Table 1.

This is a new approach, it combines the advantages of physical and interactive approaches. A review on blended learning found that this approach has a positive impact on students in physics learning (Lestari et al., 2021), due to the flexibility in allowing students to access materials at their own pace when online, and receive guidance during face-to-face sessions. However, the readiness of teachers is also a concern (Huang, Mustafa, Tlili, Chang, & Xu, 2023), teachers also need continuous professional development to design and manage blended courses effectively. Further research, as suggested in the review article, recommends future studies to evaluate the long-term effectiveness of blended learning across different subjects and educational levels. Thus, the teaching and learning of introductory physics topics still warrant research (Affriyenni, Susanti, & Swalaganata, 2020; Koes-H, Suwasono, & Pramono, 2019).

Figure 3 shows two networks of "Co-occurrence" (also known as "Co-word") analysis from using VOSViewer (van Eck & Waltman, 2010, 2014). Overall, there has been no mention of artificial intelligence in this co-word analysis. This can be seen as an opportunity to incorporate the power of artificial intelligence to create blended studies on Hooke's Law. Separately, the first network (a) shows Hooke's Law appears together with the words "Instrument test", "minimum competency assessment", "elasticity" and "critical thinking". This group is more to the testing of materials using Hooke's Law. The second network (b) has keywords that are related to the discussion in this manuscript, among which are "virtual laboratory", "computer-aided instruction", "labview", and "engineering education". However, conspicuously missing is the term "Hooke's Law" in network (b). Despite this shortcoming, based on the keywords in the clusters, the "Co-word" networks indicate that research on Hooke's Law did involve simulations. The missing keywords of PhET, YouTube and TikTok indicate that these social media platforms are yet to exist in WoS-indexed publications, which translates as the neglect of social media in high-level publications.

(a)



(b)

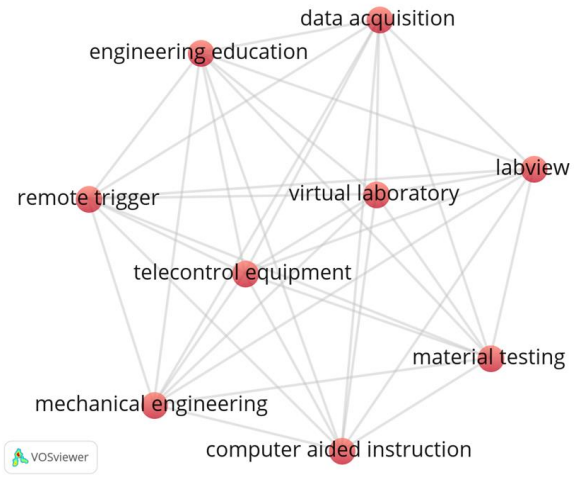


Figure 3. Two non-related networks of "Co-occurrence" analysis using "Author keywords"

CONCLUSION

Books are two-dimensional; thus, we can use technological advancement to help teachers implement better approaches in teaching and help students in learning. This article delves into the current approach to teaching and learning Hooke's Law. Based on the search in the reputable online databases for reports on teaching Hooke's Law and relevant analyses, only a handful of articles are indexed in Scopus and WoS, and they have very low citations. There are three approaches in teaching and learning of Hooke's Law, namely physical, interactive software, and blended. The blended approach is still low in count, and there are many areas in this approach that still new further research. The approach used in Hooke's Law might be suitable for other topics, especially the blended approach. It may be worth trying them in a scientific way, documenting the approach, and publishing the results to share the alternatives. Each STEM subject, such as biology, chemistry, mathematics, and engineering, has its unique characteristics, the approaches discussed here for physics could be beneficially applied to other subjects as well.

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