Bridging Theory and Practice: A Novel Educational Lab Kit for Fluid Power Instruction

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DOI: 10.18260/jet.42.2.2

Abstract

Fluid power is a multidisciplinary field crucial to various engineering applications. Introducing it early in the engineering curriculum helps students understand foundational principles critical for future work in fields such as mechanical, civil, and aerospace engineering. This paper presents a lab kit and five educational modules designed to teach core fluid power principles and support electro-mechanical technologies through hands-on activities. Each module focuses on specific learning objectives, bridging the gap between theory and practice. Students engage in activities like constructing and controlling a pneumatic gripper, calibrating a sensor with a custom-built deadweight tester, and grasping data acquisition skills using Arduino and pressure transducers. The lab kit was tested by junior and senior engineering technology students, providing a novel approach to reinforce fluid power technology concepts. Preliminary feedback suggests this approach increases student engagement, interest in fluid power, and perceived performance and competence. The kit's versatility allows for future exploration of additional fluid power concepts and learning outcomes.

1. Introduction

Fluid power is a foundational field within engineering, supporting essential applications across various sectors, including manufacturing, aerospace, and transportation. For engineering students, hands-on experience in fluid power technology is beneficial for developing a comprehensive understanding of mechanical and control systems. Introducing fluid power through practical lab work early in the curriculum helps bridge the gap between theoretical knowledge and real-world application, reinforcing essential skills and preparing students for industry demands (Chen et al. 2019; Persky and Sauret 2016).

Fluid power education faces significant challenges in providing accessible and comprehensive lab experiences. Many programs prioritize hydraulics over pneumatic systems, limiting students' exposure to the full range of fluid power applications (Assaf and Vacca 2021). High equipment costs, limited laboratory space, and difficulty replicating real-world systems further restrict practical engagement (Fox et al. 2020; Lovrec 2019). While simulations and videos are useful teaching tools, they fail to fully capture the complexities of real-world systems, leaving gaps in students' understanding (Mandal, Azad, and Rasul 2024). These challenges highlight the need for cost-effective and engaging educational solutions that align with industry advancements.

Previous studies underscore the value of lab kits as affordable, flexible tools that enhance hands-on learning, particularly in remote or resource-constrained settings. During the COVID-19 pandemic, lab kits were shown to be effective in distance learning environments, significantly improving student engagement, motivation, and cognitive outcomes (Permana 2022; Wong and Sim 2022). Moreover, Shehadi and Lucietto (Shehadi and Lucietto 2018) demonstrated that incorporating interactive, hands-on exercises in a fluid power course significantly enhanced student interest and performance. These kits allow students to conduct real-time experiments that reinforce theoretical knowledge and support the development of practical problem-solving skills (Azzam et al. 2024; Appiah-Kubi, Johnson, and Trappe 2019), addressing some of the educational gaps identified in fluid power curricula.

Recent advancements in educational tools have demonstrated the effectiveness of modular systems in providing hands-on learning experiences while addressing resource constraints in engineering education (Ma and Pecen 2024). Similarly, the modular lab kit introduced in this paper addresses these challenges by offering a cost-effective and accessible means for students to engage with pneumatic systems. Priced at ~$70, the kit includes five educational modules designed to help students explore core fluid power concepts such as actuation, sensor calibration, and data acquisition. Through activities such as constructing and operating a pneumatic gripper, students gain practical experience that builds both foundational knowledge and applied skills. This lab kit and its modular design enable students and educators to explore additional fluid power concepts.

2. Related Work

Feisel and Rosa (Feisel and Rosa 2005) and Cook (Cook 2020) highlighted the value of lab kits in enhancing problem-solving skills and practical understanding, particularly in manufacturing and engineering technology programs. Permana (Permana 2022) and Wong and Sim (Wong and Sim 2022) demonstrated that lab kits significantly improved student engagement and motivation in remote learning, making them a flexible solution in resource-constrained settings.

Studies by Fox (Fox et al. 2020), Wang (Wang et al. 2021), and Zahraee (Zahraee et al. 2023) emphasized the importance of experiential learning tools for preparing students for industry roles by providing hands-on engagement in fluid power applications. Mandal et al. (Mandal, Azad, and Rasul 2024) showed that combining simulations with physical kits enhances engagement and skill development, as simulations (Azzam, Pate, and Breidi 2023; Azzam et al. 2022) or theory (Mayer 2023) alone lack the tactile interaction needed for operational training.

Earlier efforts, such as portable kits by Zorro et al. (Zorro-Mendoza, Garcia, and Breidi 2021), Pate et al. (Pate et al. 2018) and Mishler et al. (Mishler, Garcia, and Lumkes 2011), introduced students to fundamental fluid flow concepts using simple components. While effective for teaching basics, these kits did not incorporate the electronic controls and data acquisition needed to simulate modern fluid power systems.

Unlike previous kits focused on remote learning or isolated technical concepts, our lab kit offers an adaptable and cost-effective approach to both pneumatic and hydraulic applications, making it a versatile tool for fluid power education.

3. Lab Kit

3.1. Kit Development

The lab kit provides students with hands-on experience in fundamental fluid power concepts, specifically focusing on electro-pneumatic systems to address a gap in standard curricula, which often emphasize hydraulics. Costing $72 (Table 1), the kit is designed to be affordable for institutions with limited budgets, enabling the integration of comprehensive fluid power modules. Additionally, the kit's lightweight components ensure accessibility for students with motor limitations, reducing the need for heavy lifting and making hands-on learning more inclusive.

Table 1. Budget breakdown of lab kit.

Item	Price (in U.S. Dollars $)
Junction Box	21.51
Air Compressor	15.19
LCD Screens	8.99
Arduino Microcontroller	13.59
Breadboard	1.50
Tube	3.99
Syringe	0.75
Pressure Gauge	4.50
Bolts, Hose Barbs, Hose Pushes	1.98
Total:	**72.00**

The kit's components are organized by function (Figure 1): actuation and control (pneumatic gripper and DC air pump motor), sensor calibration and measurement (pressure transducer and deadweight tester), and circuit assembly and data display (Arduino microcontroller, breadboard, and LCD screen).

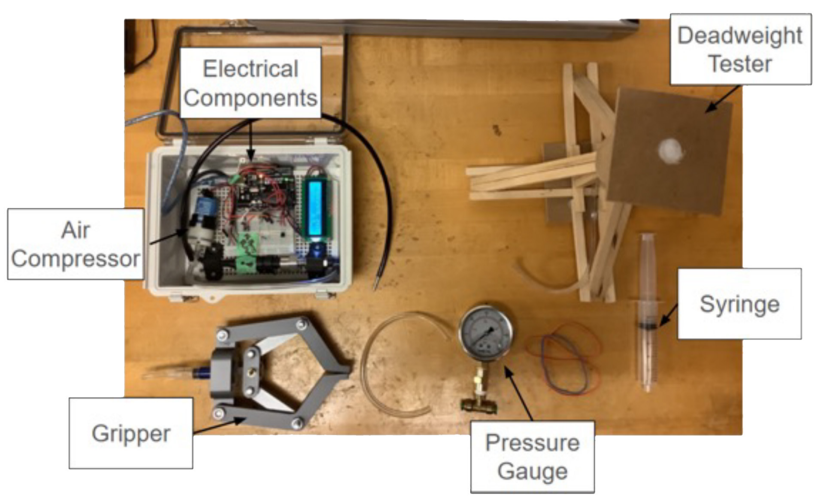

Figure 1. Complete lab kit setup for hands-on fluid power instruction.

Together, these parts allow students to explore fundamental fluid power principles, including system actuation, sensor calibration, and real-time data monitoring, within a cost-effective, modular setup that supports versatile educational use.

Through activities like assembling and controlling a 3-D printed pneumatic gripper and air pump with a microcontroller, students develop skills in electro-pneumatic actuation, simple control techniques, and system responsiveness. The kit reinforces mechanical design and assembly concepts specific to pneumatic systems, introducing students to electro-mechanical integration and circuit design with Arduino. Data collection exercises refine students' measurement skills, particularly in sensor accuracy, to ensure effective pneumatic system monitoring and adjustment. Calibration tasks emphasize sensor reliability, crucial for sustaining system performance in practical applications.

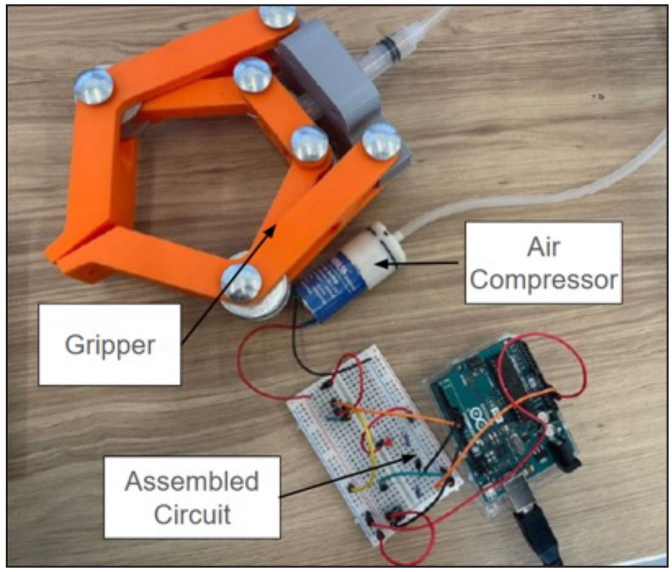

Figure 2. Pneumatic gripper actuation and control setup.

3.2. Kit Lab Modules

The lab kit and associated modules were introduced in classroom settings, where student feedback guided improvements. Initially, three modules focused on pneumatic gripper actuation and control, pressure measurement, and data acquisition using a pressure transducer (Jabbour et al. 2024). Based on the feedback previously obtained, refinements were made to enhance usability, engagement, and educational value, leading to the development of five modules. Designed for multiple uses across different courses and lab sessions, the kit features reusable components such as the pneumatic gripper, sensors, and Arduino microcontroller, ensuring longevity. Only minor consumables, like tubing or syringes, require periodic replacement, making it a cost-effective long-term solution for fluid power education. The kit's modular structure enables scalability, allowing instructors to organize students into groups and efficiently manage larger classes. Additionally, its flexibility supports expanded learning objectives, as educators can incorporate additional lab exercises. Finally, the modular design allows for easy adaptation to hydraulic systems by replacing the air pump with a hydraulic pump, enabling students to explore both fluid power domains using the same experimental setup.

3.2.1 Lab Module 1 - Pneumatic Gripper Actuation and Control

This laboratory module aims to introduce students to the principles of pneumatic actuation and control through the assembly and operation of a pneumatic gripper shown in Figure 2. Students build a light-duty gripper using 3D-printed components and assemble a circuit with an Arduino microcontroller, shown in Figure 3, to control its movement. The

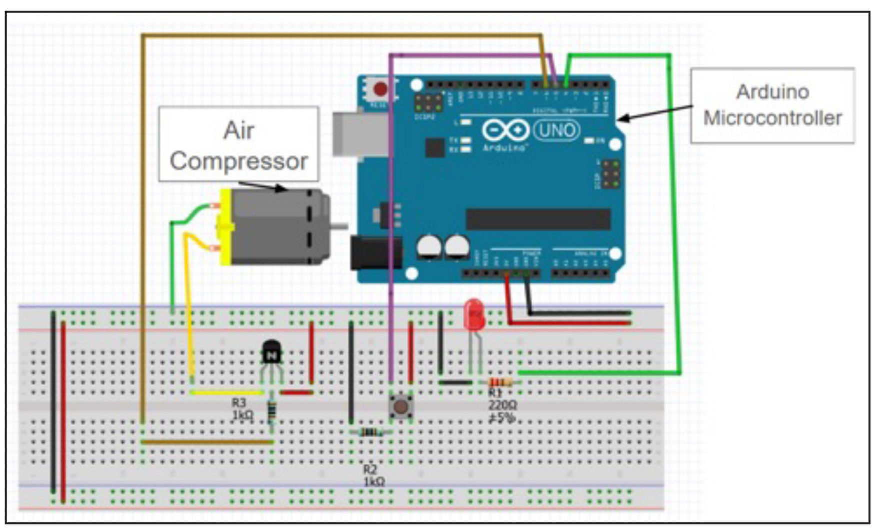

Figure 3. Circuit assembly for pneumatic gripper actuation using an Arduino microcontroller and air compressor.

students write an Arduino script to activate a mini air pump via a push button. Students learn about control techniques in pneumatic systems and observe electro-mechanical integration, gaining hands-on experience related to circuits and programming to control pneumatic mechanisms. Additionally, students are introduced to basic electric component identification and use, such as is the case for the color bands in resistors and the connected paths on a bread board.

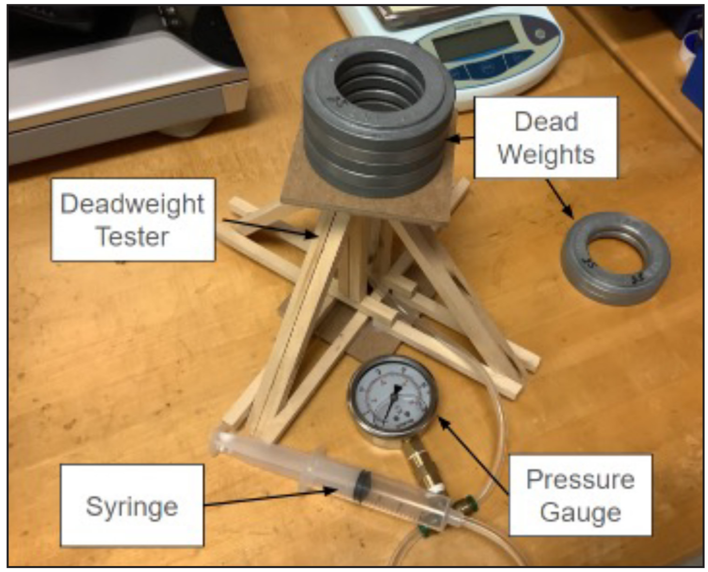

Figure 4. Deadweight tester setup with labeled components, including the syringe, pressure gauge, and dead weights.

3.2.2 Lab Module 2 - Deadweight tester and fluid power relationships

Students design and construct a deadweight tester built with balsa wood to explore the relationships between pressure, force, and area, applying Pascal's principle to pneumatic systems. Short lengths of ¼ inch tubing are used to reduce the effects of compressibility of the system. The kit shown in Figure 4 depicts the setup, including a syringe, pressure gauge, balsa wood construction, and calibrated weights (other materials with known weights may be used, like bags of rice or other cereals). Students incrementally add weights to measure the pressure load and test different fluids, such as water or air, to observe changes in system performance. This setup enables students to understand force distribution and pressure calibration in fluid power systems through hands-on assembly and testing.

3.2.3 Lab Module 3 - Data acquisition and calibration of a pressure transducer Part I

This module introduces data acquisition and sensor calibration techniques. Students use the deadweight tester (as shown in Figure 5) to generate known pressure values, which they record with a pressure transducer, then process it to establish a calibration equation for converting the transducer's voltage output to corresponding pressure values. Calibration specimens, such as known weight references, are provided to allow students to establish accurate calibration equations for the pressure transducer. The deadweight tester included in the kit serves as a calibration reference, ensuring precise sensor measurements. A manual pressure gauge is included to provide a comparative measure. Students use an Arduino microcontroller to design a circuit that captures real-time voltage readings, reinforcing skills

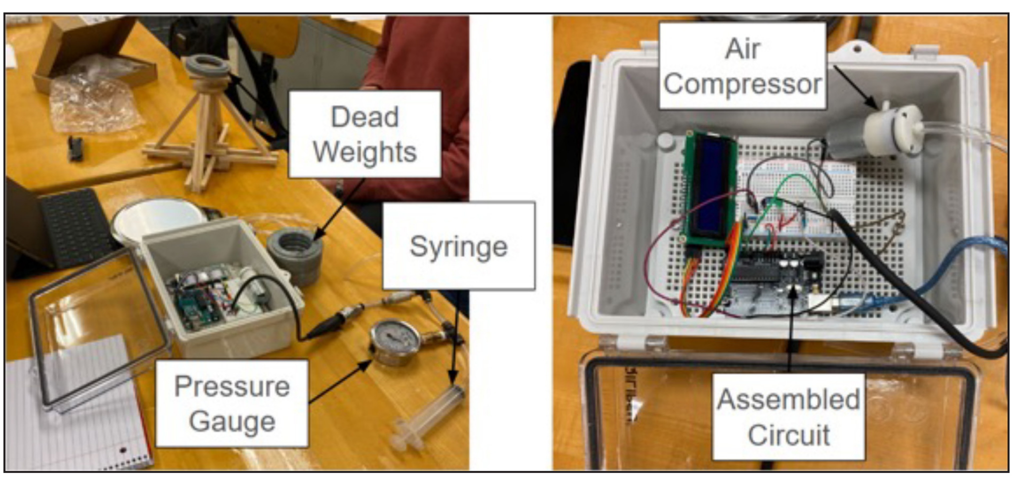

Figure 5. Lab Module 3 setup with deadweights, syringe, pressure gauge, and the assembled circuit containing the pressure transducer and Arduino microcontroller.

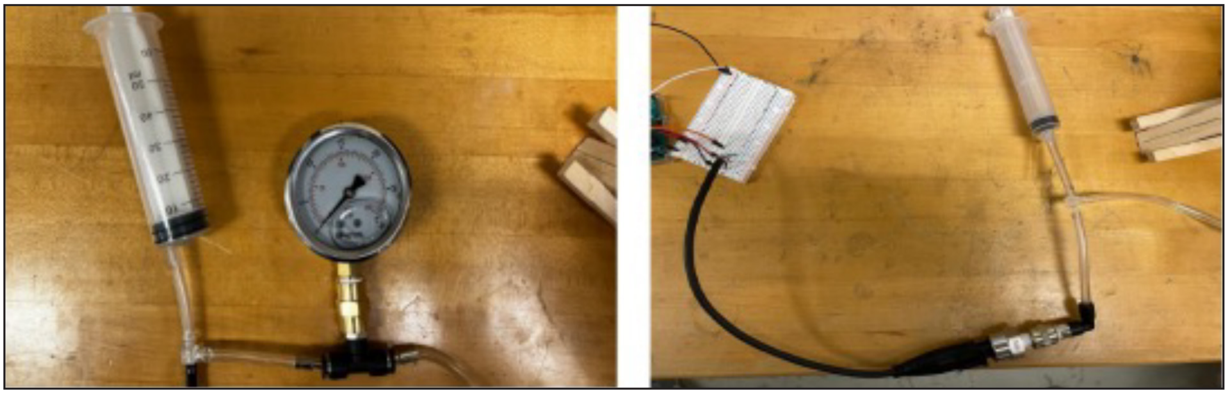

Figure 6. Pressure gauge setup (left) and pressure transducer setup (right) used in the pressure measurement module.

in circuit design, programming, and calibration for accurate measurement in pneumatic applications.

3.2.4 Lab Module 4 - Data acquisition and calibration of a pressure transducer Part II

Building on Module 3, this module focuses on real-time data display and system dynamics. Students set up a circuit with an Arduino and LCD screen to show live pressure data from a transducer integrated with a pneumatic gripper. As shown in Figure 6, students connect the transducer to observe how factors such as hose length and pump power affect system pressure. This exercise enhances students' skills in monitoring and controlling pneumatic systems, deepening their understanding of dynamic instrumentation.

3.2.5 Lab Module 5 - Pressure measurement with a pneumatic gripper using a pressure transducer

This module teaches the students the fundamentals of data collection, calibration, and pressure measurement in pneumatic systems. As shown in Figure 7, students will integrate a pressure transducer with a pneumatic gripper, utilizing an assembled circuit that includes an Arduino microcontroller, air pump, and LCD screen to display pressure data. By configuring this setup, they learn how to integrate a pressure transducer with a pneumatic gripper and hone their circuit design, instrumentation, and programming skills. Students configure the pneumatic system using an Arduino microcontroller, air pump, and pressure transducer as part of the lab process. They then use a controlled gripper actuation to gather pressure data. This configuration reinforces the ideas of sensor precision, dependability, and system monitoring by enabling students to see how pressure varies inside the system and how precise measurements may be recorded and shown.

4. Evaluation

The lab kit was administered to a group of 23 junior and senior engineering technology students enrolled in a fluid power course. Prior to students using the third, fourth, and fifth lab kit modules, a pre-survey using a Likert scale from 1 to 5 was given in order to assess its impact. This survey created a baseline for comparison by evaluating their perceived performance and competency in fluid power, as well as their level of interest in it. Following the completion of these modules, students took part in a post-survey that evaluated their engagement with the lab kit and reassessed their interest and perceived competence. The study sought to ascertain whether students' interest and perceived proficiency in fluid power

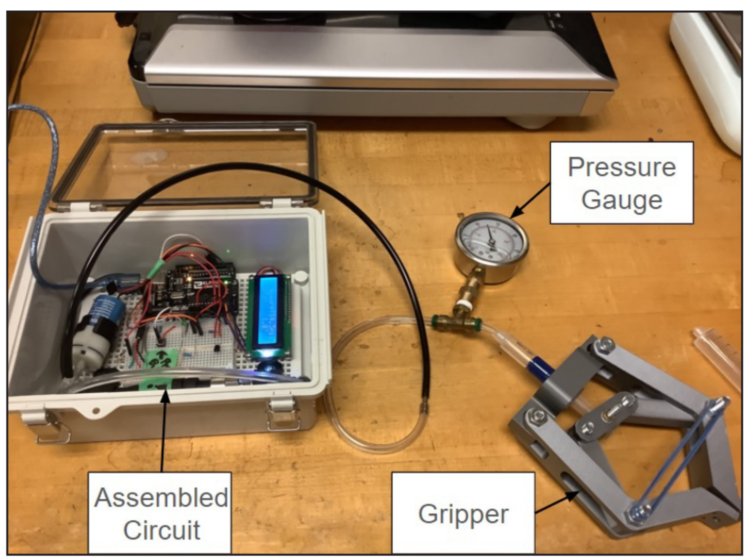

Figure 7. Experimental setup for pressure measurement module, showing the assembled circuit, pressure gauge, and pneumatic gripper.

concepts were improved by the practical experience with the lab kit by comparing their answers to the two surveys. Moreover, the engagement component of the post-survey was designed to assess how engaging students found the lab kit, providing insight into its effectiveness as a learning tool.

Figure 8 presents the average engagement scores across three dimensions: Emotional, Physical, and Cognitive Engagement, highlighting variations in student interaction with the lab kit. Among emotional engagement factors, interest in the lab kit received the highest score, indicating that students found the activities engaging and relevant. However, energy levels were relatively lower, suggesting that while students were interested, they may not have felt highly energized throughout the lab. This could be attributed to the fact that the lab kit was administered as the final lab of the semester, when students may have experienced fatigue from cumulative coursework. In terms of physical engagement, students reported high levels of effort and determination to perform well on assignments, but exertion scored the lowest, indicating that the tasks were not physically demanding. This aligns with the lab kit's design, which considers students with lower motor abilities. For cognitive engagement, students demonstrated strong focus and attention to the activities, though concentration scored slightly lower, possibly due to the demands of end-of-semester assignments and exams. Overall, students were most engaged emotionally and cognitively, while physical engagement varied depending on individual comfort levels with circuit building and hands-on tasks.

The results from the post-survey, shown in Figure 9, show that the interest in fluid power remained relatively stable with an initial high interest level (3.88 out of 5). Since their interest was already well-developed, only slight further increases were observed post-intervention (from 3.88 to 3.89). This minimal shift can be attributed to the participants being junior and senior mechanical engineering technology students who voluntarily enrolled in the fluid power course as an elective, suggesting a preexisting interest in the subject and contributing to the stability in interest levels. Conversely, perceived competence, initially lower, showed greater room for improvement and thus increased notably after hands-on experience (from 3.57 to 4.00).

Figure 10 illustrates the strongest correlations from the Lab Kit Survey, showing relationships between key engagement factors. The highest correlation (corr. = 0.90) was between enthusiasm for using the lab kit and full concentration on activities, indicating that more enthusiastic students remained highly focused. A strong correlation (corr. = 0.85) linked effort in lab tasks with learning enjoyment, suggesting that students who put in more effort found the experience more rewarding. Similarly, attention to activities strongly correlated (corr. = 0.83) with a sense of fulfillment, reinforcing that focused students felt more accomplished.

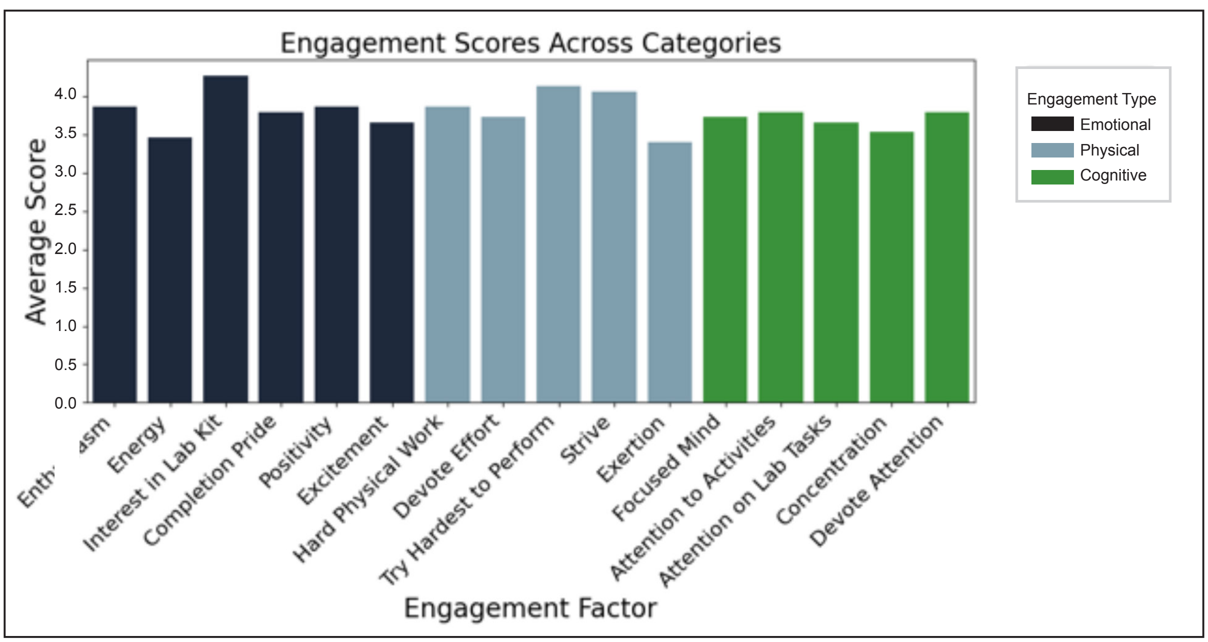

Figure 8. Engagement scores (out of 5) across different categories (Emotional, Physical, and Cognitive).

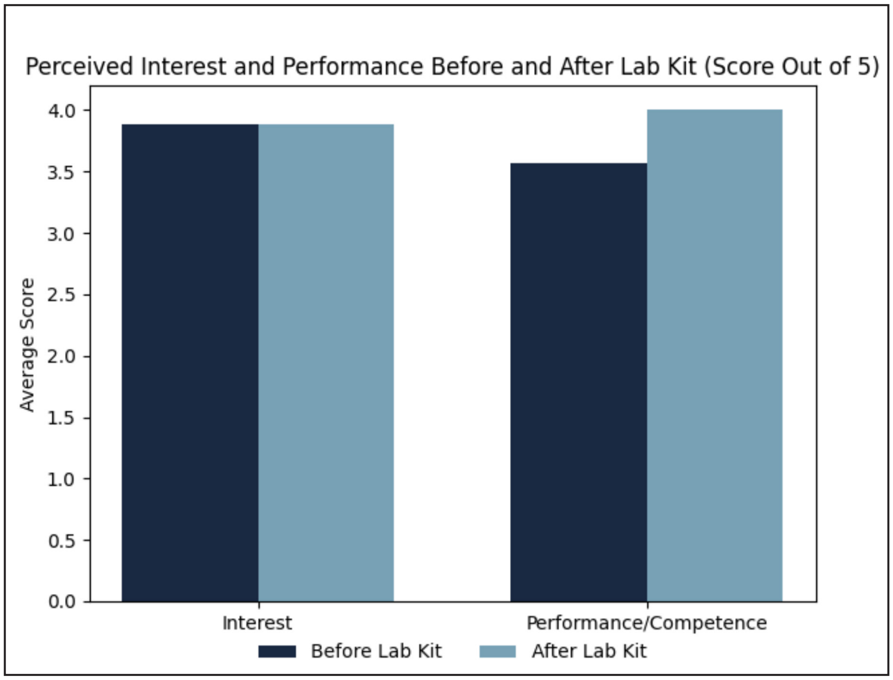

Figure 9. Comparison of students' perceived interest in fluid power and performance/competence before and after using the lab kit.

5. Discussion

The lab kit was developed to address limited hands-on opportunities in pneumatic systems within fluid power education. Unlike simulations, it provides direct interaction, reinforcing technical skills and problem-solving abilities through structured, cost-effective modules. By bridging theory and practice, the kit offers students real-world application experience in a way that traditional classroom methods cannot. Survey results confirm that the lab kit enhances student engagement, perceived competence, and interest in fluid power. Students who were enthusiastic about using the lab kit demonstrated higher concentration, and those who invested effort reported greater learning satisfaction and a stronger sense of accomplishment. While interest in fluid power remained relatively stable, perceived competence significantly improved, indicating increased confidence in applying fluid power concepts. These findings reinforce the importance of hands-on learning in motivating students and improving conceptual understanding. Additionally, the modular design enhances curricular flexibility, allowing instructors to adapt it to different instructional levels and expand learning objectives. The kit also promotes collaborative problem-solving, fostering teamwork and technical skills applicable to engineering and industry settings.

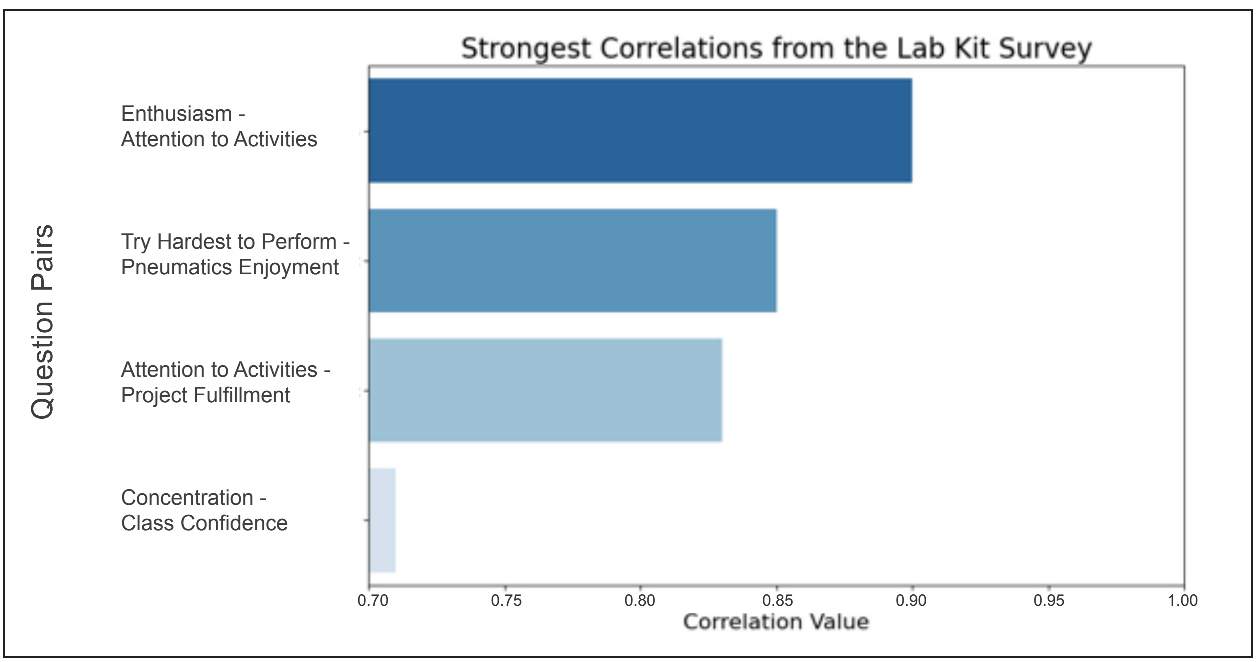

Figure 10. Strongest correlations identified in the Lab Kit Survey.

6. Conclusion & Future Work

This study presents an affordable, modular lab kit designed to enhance fluid power education through hands-on learning in pneumatic systems. It addresses gaps in traditional curricula by providing practical experience in actuation, control, data acquisition, and sensor calibration. The structured yet flexible design allows students to bridge theory and real-world applications, while also supporting hydraulic systems education. As a cost-effective alternative to conventional lab setups, the kit increases accessibility for resource-limited institutions. Survey results confirm its positive impact on student engagement, interest in fluid power, and perceived competence. While the initial results demonstrate the lab kit's potential, future iterations should focus on design refinements, module enhancements, and addressing limitations identified through student feedback. Enhancing survey methods and incorporating quantitative performance metrics will provide deeper insights into learning outcomes. Further studies with larger sample sizes and extended implementation periods are necessary to validate findings and optimize their effectiveness. Additionally, testing the kit's applicability in other fluid power courses at different institutions could support its adoption as a standardized educational resource.

References

Appiah-Kubi, Philip, Marina Johnson, and Emma Trappe. 2019. "Service Learning in Engineering Technology: Do Students have Preferences on Project Types?" *Journal of Engineering Technology* 36 (1): 32-41. https://www.proquest.com/scholarly-journals/service-learning-engineering-technology-do/docview/2237802494/se-2.

Assaf, Hassan and Andrea Vacca, 2021. "hydraulic trainer for hands-on and virtual labs for fluid power curriculum", https://doi.org/10.3384/ecp182p8.

Azzam, Israa, Keith Pate, and Farid Breidi. 2023. "Mixed Reality Technology: A Virtual Training Tool in Fluid Power Engineering." In *Proceedings of the ASME/BATH 2023 Symposium on Fluid Power and Motion Control*. American Society of Mechanical Engineers. https://doi.org/10.1115/FPMC2023-111715.

Azzam, Israa, Khalil El Breidi, Farid Breidi, and Christos Mousas. 2024. "Virtual Reality in Fluid Power Education: Impact on Students' Perceived Learning Experience and Engagement." *Education Sciences* 14 (7): 764. https://doi.org/10.3390/educsci14070764.

Azzam, Israa, Sreyan Dhar, Vinay Patil, Diptajit Maiti, Prakash Asunda, Juan Garcia Bravo, and Farid Breidi. 2022. "Gerotor Pump Simulation Modules for Enhancing Fluid Power Education." In *Proceedings of the BATH/ASME 2022 Symposium on Fluid Power and Motion Control*. American Society of Mechanical Engineers. https://doi.org/10.1115/FPMC2022-88469.

Chen, Guo, Jiangen Zheng, Liyu Liu, and Lei Xu, 2019. "Application of microfluidics in wearable devices", Small Methods(12), 3. https://doi.org/10.1002/smtd.201900688

Cook, Kevin. 2020. "Development of Modular Fixturing Lab Kits to Enhance Design for Manufacturing Learning." *Journal of Engineering Technology* 36(1): 14-24.

Feisel, Lisa D., and Albert J. Rosa. 2005. "The Role of the Laboratory in Undergraduate Engineering Education." *Journal of Engineering Education* 94(1): 121-130.

Fox, Patricia, Brandon Sorge, Martin E. Gordon, Scott Danielson, Ronald Land, I. R. Nettey, Thomas J. Perry, Kim W. Gaines, and John Irwin. 2020. "What is the Future of Engineering Technology?" *Journal of Engineering Technology* 37 (2): 48-59. https://www.proquest.com/scholarly-journals/what-is-future-engineering-technology/docview/2476614647/se-2.

Jabbour, H., I. Azzam, I. E. Lago, F. Breidi, and J. M. Garcia. 2024. "Development of Design, Control, and Data Acquisition Modules for Fluid Power Education." Paper presented at the 2024 ASEE Annual Conference & Exposition, Portland, OR. https://doi.org/10.18260/1-2--47182.

Lovrec, Darko. 2019. "Education in the Field of Fluid Power Technology - Challenges, Opportunities and Possibilities." In *Proceedings of the 2019 International Conference on Hydraulics and Pneumatics (HERVEX)*, 12–23. Băile Govora, Romania: HERVEX.

Mandal, Nirmal Kumar, Abul Kalam Azad, and M.G. Rasul. 2023. "On Students' Learning Experience of Fluid Power Engineering – Impact of Simulation Software." *International Journal of Mechanical Engineering Education* 52 (2): 143–156. https://doi.org/10.1177/03064190231176133.

Ma, Junkun and Reg Recayi Pecen. 2024. "Incorporating the Design and Development of an Educational Automated Manufacturing System Utilizing Desktop Equipment into Instruction of various Courses." *Journal of Engineering Technology* 41 (2): 6-14. https://www.proquest.com/scholarly-journals/incorporating-design-development-educational/docview/3163944564/se-2.

Mayer, Jennifer. 2023. “Open Educational Resources (OER) Efficacy and Experiences: A Mixed Methods Study.” portal: Libraries and the Academy 23 (4): 773–798. https://doi.org/10.1353/pla.2023.a908701.

Mishler, L. A., J. M. Garcia, and J. H. Lumkes. 2011. “Engaging Pre-College Students in Engineering Using Hands-on Micro-Processor Controlled Portable Fluid Power Demonstrators.” In *Proceedings of the 2011 ASABE Annual International Meeting*, Paper No. 1111500. https://doi.org/10.13031/2013.

Pate, Keith, Joseph David Marx, Abdallah A. Chehade, and Farid Breidi. 2018. “Design of a Transparent Hydraulic/Pneumatic Excavator Arm for Teaching and Outreach Activities.” *Proceedings of the 2018 ASEE Annual Conference & Exposition*. https://peer.asee.org/30390

Permana, Adhitya Chandra. 2022. “Lab Kit Development to Improve Student’s Attitudes and Achievements in Distance Learning.” *Eduproxima: Jurnal Ilmiah Pendidikan IPA* 4(1): 1-12.

Persky, Rodney and Emilie Sauret, 2016. “Preliminary and robust design analysis of a solar thermal power block”, *Volume 2C: Turbomachinery*. https://doi.org/10.1115/gt2016-57172.

Rodriguez, Luis A., Daniel Williams, and Michael D. Cook. 2019. “Development of a Motion Control Laboratory Focusing on Control Design and Fluid Power Education.” *Proceedings of the American Society for Engineering Education Annual Conference.*

Ryan, Saxon J., Brian L. Steward, and Safal Kshetri. 2021. “Simulated Hands-On Laboratory Instruction for Fluid Power Systems.” 2021 ASABE Annual International Virtual Meeting, July 12-16, 2021, January. doi:10.13031/aim.202100684.

Shehadi, Maher, and Anne Lucietto. 2018. “Engineering Technology Students’ Response to Hands-on Fluid Power Exercises.” *International Journal of Engineering and Advanced Technology* 7 (5): 81–88. https://doi.org/10.35940/ijeat.e5403.065518.

Wang, Jia-Chang, Tim Pasang, Manuel Ruilova, Laveda Pasang, Cho-Pei Jiang, Kate Edwards, Nick Van der geest, and Mike Protheroe. 2021. "Truly Hands-on 3D Printing: A Case Study from Taiwan." *Journal of Engineering Technology* 38 (1): 46-54. https://www.proquest.com/scholarly-journals/truly-hands-on-3d-printing-case-study-taiwan/docview/2526350106/se-2.

Wong, Hee Ting, and Siong Fong Sim. 2022. “A Curriculum-Based Laboratory Kit for Flexible Teaching and Learning of Practical Chemistry.” *Chemistry Teacher International* 4(4): 343–353. doi:10.1515/cti-2022-0014.

Zahraee, Afshin, Cheng Zhang, David Pratt, and Chandramouli V. Chandramouli. 2024. "Vertical Integration of Experiential Learning in Construction Curriculum with Industry Collaboration." *Journal of Engineering Technology* 41 (1): 8-12. https://www.proquest.com/scholarly-journals/vertical-integration-experiential-learning/docview/3089914190/se-2.

Zorro-Mendoza, C. J., J. Leon-Quiroga, B. Newell, and J. Garcia. 2021. “Electro-Hydraulic Excavator 2.2: Teaching Fundamental Concepts in Fluid Power.” *Technology and Engineering Teacher* 80 (February): 80.

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