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# Active Learning in Fluid Mechanics: Low Cost Hands-On Activities for Understanding of Valve Types

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## Abstract

Background - Hands-on and active learning strategies have been widely for their effectiveness in enhancing engineering education, particularly in bridging theoretical knowledge with practical application.
Purpose - This study investigates the implementation of such strategies through a valve identification activity conducted in an undergraduate engineering course.
Method/approach - The study was conducted through a structured 2.5-hour session, beginning with 1.5 hours of theoretical instruction followed by 1 hour of practical work. During the activity, students worked in pairs to identify and classify various valve types using prepared worksheets. Data were collected from classroom observations, student worksheets, and feedback via a Google Form distributed after the semester concluded.
Findings - The results revealed that the activity significantly improved students' understanding of valve types and their functions, while also promoting critical thinking and collaboration. Students also suggested improvements, including a broader variety of valves and more interactive components.
Conclusions - The findings suggest that this approach offers an accessible and effective method for incorporating practical valve identification into engineering courses.
Novelty/Originality/Value - The novelty of this work lies in demonstrating a scalable and low-cost hands-on activity that integrates immediate application, peer collaboration, and formative feedback to reinforce learning outcomes.

**Keywords:** active learning; hands-on learning; engineering education; practical learning; valves identification

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## INTRODUCTION

Fluid flow is a fundamental and important subject for chemical engineering students. In the chemical process industry, fluid flow applications are common and essential. Valves are among the most commonly used pieces of equipment in these applications. They are being used to regulate the flow or pressure of fluids, performing vital functions like stopping and starting flow, controlling flow rate, diverting flow, preventing backflow, controlling pressure, or relieving pressure (Cengel et al., 2024). It is essential that they are studied and understood in depth. Given their critical role, the proper selection, operation, and maintenance of valves are essential skills for chemical engineers. Valve selection is a particularly important skill. Chemical engineers must choose the right valve for specific applications. This involves understanding different types of valves, such as gate valves, globe valves, ball valves, butterfly valves, and check valves, each suited for different conditions (Sotoodeh, 2023). Chemical engineers need to ensure that each valve meets the specific requirements of the process, including pressure, temperature, flow rate, and the chemical nature of the fluids (Bhowmik, 2023). Both theoretical knowledge and practical familiarity with real-world equipment are necessary to optimize process efficiency and safety.

Practical familiarity with industrial equipment, which also applies to valves, enhances engineers' ability to troubleshoot processes and apply effective solutions (Prpich, 2024). Therefore, integrating hands-on learning with theoretical instruction is essential for developing competent and practice-ready chemical engineers. However, understanding valves can be challenging due to their complexity. Valves are complex mechanical devices with various types, each designed for specific functions and operating conditions. This complexity can make it difficult for students to grasp the differences and appropriate applications of each valve type. Additionally, traditional teaching methods may not effectively convey the practical aspects of valve operation and selection. Traditional methods such as lectures and textbooks often struggle to make valve concepts tangible for students (Barner et al., 2022). Ensuring that students develop both theoretical knowledge and practical skills is crucial for their future roles as engineers. This idea also aligns with the Accreditation Board for Engineering and Technology—ABET (called EC2000) (Arruda et al., 2021).

Another challenge is that although valves are very important, they are taught as part of the fluid mechanics course along with other essential topics, which limits the time available for valve instruction. This constraint means that the slot for teaching valves is often quite brief. Consequently, there is a need for innovative teaching approaches to ensure that students can still gain a comprehensive understanding of valves within a limited timeframe. For instance, within a typical 2.5-hour session (3-credit course), it becomes crucial to use effective and engaging teaching methods that can provide students with a solid grasp of valve types, their functions, and practical applications. To address those challenges, hands-on learning approaches are introduced to provide practical experiences alongside theoretical instruction. In this paper, a hands-on teaching approach is designed to help chemical engineering students gain a better understanding of valve types. Through a combination of classroom teaching and an activity involving physical valves, the author aimed to make valve concepts more accessible and engaging. They allow students to experience real-world scenarios and gain practical knowledge efficiently, despite the restricted time allocated for each topic in the fluid mechanics curriculum. The goal of this research is to contribute to effective teaching practices in engineering education by sharing methodology, implementation, and outcomes.

Active learning as a teaching method can include diverse forms of engagement, including increased physical activity, interaction, social collaboration, deeper processing, elaboration, material exploration, or metacognitive monitoring (Venton et al., 2021, Skalka et.al., 2022, Hussadintorn et al., 2024). Active learning involves brief, course-related activities for individuals or small groups, which all students participate in during class. These activities can be interspersed with instructor-led sessions where student responses are discussed, and new information is introduced (Felder & Brent, 2024). Traditional (engineering) teaching methods, including lectures, exercises, and lab work, are the opposite of active learning. Such traditional methods have faced criticism for not adequately preparing students to collaborate and engage in active learning behaviours, which prioritize student interaction (Børte et al., 2023). Active learning frequently incorporates group work and places a strong emphasis on higher-level thinking skills (Higgs, 2021).

Hands-on learning, a subset of active learning, emphasizes learning by doing (Su, et al., 2023). This experiential approach allows students to directly engage with the material, fostering a deeper understanding of the subject matter (Kong, 2021). Hands-on activities are based on real-world problems and encourage students to build their knowledge through direct experience and action. By working on these activities, students grasp fundamental concepts and enhance their problem-solving and critical-thinking abilities (Gautam et al., 2020). By manipulating physical objects and observing the outcomes of their actions, students can better understand abstract ideas and apply them in practical contexts (Rau, et al., 2021). In the field of engineering education, hands-on learning is particularly valuable (Vodovozov et al., 2021). Engineering concepts often involve complex systems and processes that can be difficult to understand through lectures alone. Student participation in activities that promote learning through direct experience, followed by reflection, better equips them for technology and knowledge-based careers. When hands-on experiences are thoughtfully designed, students can move beyond lecture content to see how theoretical concepts are applied in real-world situations (Ferri et al., 2020).

The ability to be able to be applied theory in practice is crucial because engineering education must equip graduates with comprehensive knowledge, practical skills, and technical capabilities that are essential in the industry (Souppez, 2025). Graduates should be prepared to meet the demands of the workforce, which require not only understanding theoretical concepts but also applying them in practical scenarios (Mekala et al., 2020). By fostering this ability, engineering programs must ensure that their students are well-prepared to tackle real-world challenges, innovate within their fields, and contribute effectively to their professional environments. This alignment with industry requirements is vital for maintaining the relevance and effectiveness of engineering education in producing competent engineers (Dhia, 2023). In this study, the implementation of an active, hands-on learning activity focused on valve identification in an engineering course was explored. Given the challenges of sourcing industrial-grade valves, the study utilized affordable, readily available alternatives to provide students with practical, engaging learning experiences. Through careful preparation and structured activities, the aim was to enhance students' understanding of valve types and functions, while also fostering a deeper appreciation for the practical applications of their theoretical knowledge.

## METHODS

This section provides an explanation of the methodology used to implement an active learning method on valve identification and how to evaluate it. The educational practice involved a structured approach to learning about valves, combining theoretical instruction with active learning activity. Students were able to work collaboratively during the session, encouraging peer interaction and knowledge sharing.

### Participants

Participants included students from the undergraduate chemical engineering program in the second year who are enrolled in Fluid Mechanics subject. There is a total of nine students who are involved. The instructors' role was as facilitators in the activity.

### Preparation

Seven different types of valves were ordered in advance. Upon receiving the valves, each one was labelled with a unique identifier (A, B, C, etc.) to distinguish them for the activity. These labelled valves were then placed on a separate table in the classroom, organized to ensure easy access for the students during the practical session. This careful preparation was essential to ensure a smooth and effective implementation of the active learning component.

In addition to preparing the valves, a printed worksheet was also prepared in advance. The worksheet contained a table for students to fill out, identifying the type of valve and providing reasons for their classification. This worksheet was designed to guide the students' observations and ensure a structured approach to the activity.

### Implementation

The activity was conducted during a 2.5-hour session dedicated to the topic of valves. In the first 1.5 hours of the session, the instructor delivered theoretical instruction covering the types of valves, their functionality, and real industrial applications. Following this instructional segment, the session transitioned to the active learning phase, which lasted for another 1 hour. Prior to the active learning phase, students received instructions and guidance on how to approach the task. Each student pair was provided with a set of labelled valves (A, B, C, etc.) that is prepared in advance and a corresponding worksheet. Students worked collaboratively in pairs to observe, identify, and classify the valves using the theoretical knowledge they had just learned.

### Assessment

Assessment of student learning occurred informally through observation and interaction during the activity. The instructor circulated among students, providing guidance and feedback as needed. Additionally, completed tables served as tangible evidence of student understanding and were reviewed by the instructor for accuracy and depth of reasoning. The instructor facilitated a class discussion following the activity to debrief and reinforce key concepts. During the discussion, students were encouraged to reflect on their learning process and discuss any challenges or insights together.

### Feedback

To understand the students' experiences and the lasting impact of the activity, a Google Form was used to collect feedback. The form was distributed after the semester ended, rather than right after the session, to see if students still remembered the activity weeks later. This feedback helped assess the long-term effectiveness of the hands-on learning experience. This feedback is important to make sure that the educational practice remains effective and responsive to student needs. This feedback is also necessary for making future improvements to this activity.

### Data collection and analysis

Data from each step of the educational practice was collected through observation and documentation. The instructor observed student interactions and the processes they employed to identify and classify the valves. Completed worksheets served as tangible evidence of student understanding and were reviewed by the instructor for accuracy and depth of reasoning. Additionally, data from feedback forms were also collected and analyzed to gain further understanding of the students' experiences and to inform future improvements to the educational practice. The collected data were analyzed qualitatively to assess the effectiveness of the educational practice. The analysis focused on identifying patterns in student responses, particularly regarding their understanding and engagement. This analysis aimed to determine how well the activity facilitated active learning and helped students grasp the principles of valve identification

## RESULTS AND DISCUSSION

### Valve selection and preparation

Providing affordable hands-on learning experiences with valves presents several challenges. It was difficult to obtain industrial-grade valves due to some issues, such as high costs, long procurement times, and large sizes. To address this, the instructor opted for valves that were affordable, readily available, and manageable size of the valves to facilitate handling in the classroom environment.

A budget limit of less than 200,000 Indonesian Rupiah for each valve led to a thorough search on different e-commerce platforms. Despite these valves being of lower cost and

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potentially differing in size or material compared to industrial-grade counterparts, they still offered valuable learning opportunities for students. The following seven valves, which were ultimately selected to facilitate the hands-on learning activity, are provided in Table 1 and Figure 1. These valves were chosen based on criteria of affordability, availability, and diversity to maximize student engagement in the learning experience.

**Table 1.** List of selected valves for hands-on learning activity with price

| Valves name | Price |
|---|---|
| Butterfly valve | Rp 114.000,- |
| Gate valve | Rp 41.500,- |
| Globe valve | Rp 70.000,- |
| Ball valve | Rp 21.168,- |
| Check valve | Rp 47.000,- |
| Needle valve | Rp 49.000,- |
| PVC Ball valve | Rp 16.400,- |

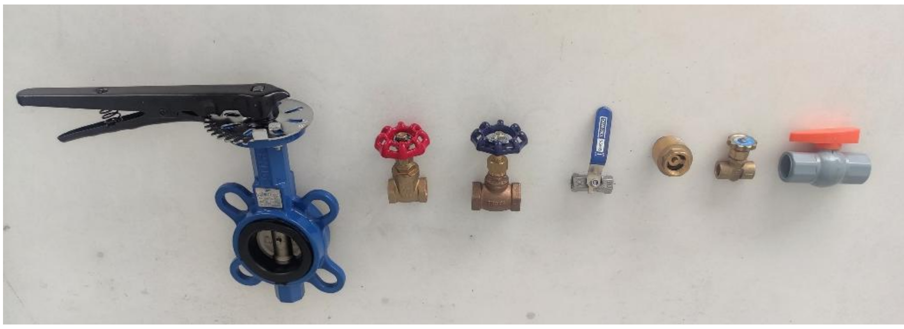

**Figure 1.** Photo of selected valves for hands-on learning activity

## Observation during activity

During the activity, students were engaged in identifying and classifying the valves. The pairing allowed peer learning, as students discussed their observations and reasoning with their partners. It was observed that students frequently referred to the theoretical knowledge provided during the initial instruction, demonstrating an integration of theoretical and practical learning. Students were seen to be highly enthusiastic about handling and opening the valves. Generally, to identify the type of valve, the internal parts need to be examined. Students were seen lifting, inspecting, and closely observing the interior of the valves. They used various methods to get a clearer view, including peering inside and rotating the valves. Afterward, they continued by discussing their observations with each other, sharing their findings, and confirming their conclusions about the valve types. This observation highlights the high level of interest and engagement among the students in understanding the material, as well as their willingness to collaborate in solving the problems presented.

The instructor observed that most students were able to correctly identify the types of valves and provide justifiable reasons for their classifications. This indicated a good understanding of the material provided prior to the activity. Some valves, however, required additional guidance and clarification, particularly when dealing with less familiar valve types. One notable challenge was the check valve, which students often mixed up with the pressure relief valve due to their similar mechanisms. This confusion highlights the need for more detailed instructions or visual aids to differentiate between similar valve types. Overall, the observations during the activity indicated that the hands-on learning approach was effective in enhancing student engagement and understanding of valve types and functions. The instructor's real-time feedback and guidance further supported student learning and ensured that misunderstandings were promptly addressed.

After the observation, all students gathered and had discussions with the instructor. This discussion was useful to provide qualitative data on student learning experiences. During this discussion, students were encouraged to share their insights, challenges, and reflections on the activity. This dialogue provided further context to the observational and worksheet data, allowing for a comprehensive assessment of the educational practice's effectiveness. The class discussion revealed that students appreciated the hands-on approach, and many expressed that the activity helped them better understand the material.

### Worksheet

The worksheet was prepared on a single A4-sized sheet of paper. At the top, clear and concise instructions were provided to guide the students through the activity. Below the instructions part, a table was included with three columns. The first column was designated for the valve number, the second column for the valve type, and the third column for the students to explain the reasoning behind their classification. This third column was important as it provided insight into the students' understanding and the rationale behind their decisions. A blank worksheet is shown in Figure 2. Even though they did the activity in pairs, each student was asked to complete the worksheet individually. The worksheet served as a tangible record of their observations and reasoning. The completed worksheets were collected and reviewed by the instructor to assess the accuracy and depth of student understanding.

The accuracy and depth of reasoning in the completed worksheets varied among students. Most students correctly identified the valves and provided reasonable justifications for their classifications. Common errors were misidentifying valves with similar mechanisms and providing insufficient explanations for their choices. As discussed before, for example, some students confused check valves with pressure relief valves due to their similar mechanisms. This underscores the need for more detailed instruction or visual aids to help students distinguish between similar valve types. The worksheets also highlighted the effectiveness of hands-on activity in reinforcing learning. Students who were more engaged during the practical session tended to perform better on the worksheets, demonstrating the value of active learning approaches in enhancing retention and understanding. The collaborative nature of pairing up students also seemed to benefit, as those who worked well with their partners produced more accurate and detailed responses.

Based on the filled worksheets, it was found that the diversity of the selected valves played a crucial role in broadening the students' understanding. By encountering a range of valve types, students were able to apply their knowledge more flexibly and develop a more comprehensive understanding of valve functions and applications. Overall, the analysis of the worksheets provided valuable insights into the strengths and weaknesses of the educational practice approach. It confirmed that while the hands-on activity was generally effective, there are opportunities for improvement, particularly in addressing common areas of confusion and ensuring all students can articulate their understanding clearly.

### Feedback form

The feedback collected from the students regarding the active learning session on valve identification provides valuable insights into the effectiveness of the activity and areas for improvement. The Google Form feedback survey included nine questions on several aspects of the session, such as the overall interest in the activity, clarity of instructions, effectiveness of theoretical instruction, recall of the activity, and suggestions for improvement. The screenshot of the questions in the Google form is shown in Figure 3.

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Nama:

***Guess the Valve: Exploring Valve Types***

Di dalam kelompok, perhatikan dengan seksama setiap *valve* yang telah disiapkan. Isilah lembar kerja yang tersedia.

Terdapat 7 *valve*. Kolom "VALVE NO" diisi dengan nomor *valve* yang tertera. Kolom "JENIS VALVE" diisi dengan tebakan Anda jenis *valve* apakah yang sedang Anda amati. Kolom "ALASAN" diisi dengan uraian alasan mengapa Anda menganggap *valve* tersebut adalah jenis yang Anda tebak.

| VALVE NO | JENIS VALVE | ALASAN |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

**Figure 2**. Blank worksheet

Seberapa menarik aktivitas ini menurut Anda? *
[1 (Tidak menarik) hingga 5 (Sangat menarik)]
1 2 3 4 5
Tidak menarik ○ ○ ○ ○ ○ Sangat menarik

Seberapa jelas instruksi yang diberikan untuk aktivitas ini? *
[1 (Tidak jelas) hingga 5 (Sangat jelas)]
1 2 3 4 5
Tidak jelas ○ ○ ○ ○ ○ Sangat jelas

Seberapa baik teori yang diajarkan di dalam kelas sebelum aktivitas dapat mempersiapkan Anda melakukan aktivitas ini? *
[1 (Tidak baik) hingga 5 (Sangat baik)]
1 2 3 4 5
Tidak baik ○ ○ ○ ○ ○ Sangat baik

Berapa tingkat kesulitan aktivitas ini menurut Anda? *
[1 (Tidak sulit) hingga 5 (Sangat sulit)]
1 2 3 4 5
Tidak sulit ○ ○ ○ ○ ○ Sangat sulit

Apakah aktivitas ini membantu Anda memahami valve dengan lebih baik? *
[1 (Tidak sama sekali) hingga 5 (Sangat membantu)]
1 2 3 4 5
Tidak sama sekali ○ ○ ○ ○ ○ Sangat membantu

Seberapa yakin Anda akan mampu mengidentifikasi berbagai jenis valve setelah melaksanakan aktivitas ini? *
[1 (Tidak yakin) hingga 5 (Sangat yakin)]
1 2 3 4 5
Tidak yakin ○ ○ ○ ○ ○ Sangat yakin

Apakah Anda merasa bahwa aktivitas ini berharga bagi pembelajaran Anda? *
[1 (Tidak berharga) hingga 5 (Sangat berharga)]
1 2 3 4 5
Tidak berharga ○ ○ ○ ○ ○ Sangat berharga

Seberapa baik Anda mengingat aktivitas ini, mengingat bahwa itu terjadi beberapa waktu yang lalu? *
[1 (Tidak ingat) hingga 5 (Sangat ingat)]
1 2 3 4 5
Tidak ingat ○ ○ ○ ○ ○ Sangat ingat

Berikan saran dan masukan untuk aktivitas ini agar dapat dilakukan kembali dengan lebih baik dan bermanfaat bagi mahasiswa. *
Your answer

**Figure 3.** Feedback form questions

In terms of interest level, most students found the activity highly engaging, with the majority rating it a 5 out of 5. This high level of interest suggests that hands-on learning activities are effective in capturing students' attention and promoting engagement. The active participation required in the session likely contributed to maintaining student interest and involvement. The clarity of instructions was also rated highly, with most students giving it a 5 out of 5. This indicates that the instructions provided were clear and understandable, which is crucial for the success of any educational activity. Clear instructions ensure that students can follow the procedure without confusion, leading to a smoother learning experience.

Regarding the preparation through theoretical instruction, it was found that theoretical instruction provided prior to the activity was well received, with most students rating it a 5 out of 5. This suggests that the theoretical background adequately prepares students for the hands-on activity, highlighting the importance of a solid theoretical foundation before engaging in practical exercises. When asked about their memory of the activity, students gave mixed responses, with some rating it as high as 5 and others as low as 2. This variation indicates that while the activity was memorable for some, others may need additional reinforcement to retain the information over a longer period. This points to a need for periodic reviews or follow-up activities to reinforce learning.

The last part of the form is an open question for students to provide constructive suggestions for enhancing the activity. The feedback highlighted is summarized in Table 2.

**Table 1.** Summarized feedback from students

| Topic | Feedback |
|---|---|
| Increased variety of valves | To provide more types of valves to broaden their knowledge. |
| Individual and group work | To offer the activity in both individual and group formats. |
| Valve disassembly | To cut valves open either vertically or horizontally for a clearer view of their internal structures. |
| Interactive games | To incorporate games related to valve identification was also suggested, which could make the learning process more enjoyable and reinforce knowledge through playful engagement. |

Overall, the feedback from the students underscores the value of hands-on learning activities in engineering education. The high engagement and clarity ratings affirm that the approach is effective, while the mixed recall ratings and suggestions for improvement provide a roadmap for enhancing future activities. Incorporating more valve types, offering individual and group formats, providing internal views of valves, and integrating interactive elements can make the learning experience more comprehensive and memorable. By continuously refining the approach based on student feedback, educators can ensure that practical learning sessions not only enhance theoretical understanding but also equip students with the skills needed for their future careers in engineering.

## Recommendation for future activity

Based on the observations, worksheet, and feedback from this study, several recommendations can be made to enhance future hands-on learning activities in a similar engineering subject. These recommendations aim to address the challenges encountered, incorporate student suggestions, and optimize the learning experience for greater engagement and understanding. One of the primary recommendations for enhancing the valve identification activity is to increase the variety of valves included. Students expressed a desire to explore a broader range of valve types to better understand their characteristics and applications. Future activities should feature both common and less familiar valve types—such as gate valves, globe valves, ball valves, butterfly valves, check valves, and pressure relief valves—with variations in materials like metal and plastic. This diversity will help students develop a more comprehensive understanding of valve functionalities and their specific uses in industrial settings.

In addition to increasing variety, incorporating more complex valves can offer greater challenges and stimulate critical thinking. Valves with intricate mechanisms or multiple functions, such as control valves that regulate flow and pressure based on external signals, can introduce students to advanced concepts in fluid dynamics and control systems. However, it is important to note that including such valves may increase the overall cost of the activity. To reinforce the learning objectives, structured reflection and discussion sessions should follow the hands-on activity. These sessions provide students with opportunities to share observations, discuss their reasoning, and clarify any misconceptions. Facilitated peer-to-peer discussions and guided

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reflections led by the instructor can deepen students' understanding and solidify their learning. When documented properly, these sessions become valuable data sources for evaluating student comprehension, identifying recurring themes, and refining instructional strategies.

Providing enhanced instructional materials can further support student learning. Detailed manuals or guides that explain the characteristics, functions, and typical applications of each valve type can serve as essential references. Additionally, incorporating multimedia resources—such as instructional videos or interactive simulations, prior to the activity—can cater to various learning styles and enhance overall understanding. Feedback collection should occur both immediately after the activity and at a later stage to gain a well-rounded perspective of its effectiveness. Immediate feedback can capture students' first impressions and any challenges faced during the activity. Long-term feedback, such as responses gathered at the end of the semester, can offer insights into retention and lasting impact. Comparing these two types of feedback can help identify areas for improvement and assess the activity's long-term value.

Although budget constraints were successfully managed in this study, future implementations should continue seeking cost-effective solutions. Procuring valves from e-commerce platforms proved feasible, but establishing partnerships with local suppliers or industries may provide more consistent access to quality materials. Securing grants or funding specifically for educational tools can also help overcome budget limitations and allow for a more diverse and high-quality equipment set.

For broader impact, the activity could be scaled to accommodate larger classes or integrated into other relevant courses. Developing a scalable model with clear guidelines and adaptable materials would support wider adoption among educators. Integrating the activity into courses such as fluid mechanics, process engineering, or instrumentation and control can provide students with multiple opportunities to apply their knowledge in different contexts. Finally, establishing a continuous feedback loop is essential for ongoing improvement. Regularly gathering input from both students and instructors can help identify new challenges and guide iterative enhancements. This process will ensure that the activity remains relevant, effective, and engaging for future cohorts.

## CONCLUSION

This study highlights the effectiveness of an active, hands-on valve identification activity in an engineering course. By using affordable valves, the activity offered practical learning without relying on industrial-grade equipment. Combining theory with practice improved student understanding of valve types and functions. High engagement, collaboration, and positive feedback indicated strong learning outcomes. Worksheets showed students could apply theory in context, while end-of-semester reflections confirmed lasting impact. Students suggested improvements such as increasing valve variety and adding interactive elements. Despite strong preparation, mixed recall ratings suggest follow-up is needed to reinforce learning. Overall, the study demonstrates that hands-on strategies can bridge theory and practice, enhance comprehension, and build critical skills like problem-solving and teamwork, making them valuable tools in engineering education.

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