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Enhancing Student Understanding of Shift Register Concepts Using an Interactive Visualization and Hands-On Learning Approach

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ABSTRACT – This study presents an innovative teaching and learning approach to improve students' understanding of shift register concepts in Digital Electronics. Students often face difficulties in visualizing data movement and distinguishing between different register operations such as Serial-In Serial-Out (SISO), Serial-In Parallel-Out (SIPO), Parallel-In Serial-Out (PISO), and Parallel-In Parallel-Out (PIPO). To address this issue, an interactive learning framework integrating visualization and hands-on learning using a developed shift register trainer kit was proposed. The approach enables real-time observation of data movement through LED visualization, allowing students to better understand sequential data flow based on clock signals. A quasi-experimental study involving 90 students from three engineering programmes was conducted using pre-test and post-test assessments. The results show a significant improvement in students' performance, with the mean score increasing from 5.13 to 8.33, representing a 62.4% improvement. The findings indicate that the proposed approach enhances conceptual understanding, improves students' ability to interpret data flow mechanisms, and reduces reliance on memorization. This study demonstrates that integrating visualization and hands-on learning provides an effective strategy for improving learning outcomes in Digital Electronics education.

KEYWORDS : Shift Register, SISO, PIPO, Digital Electronics, Teaching Innovation, Visualization Learning

1.0 INTRODUCTION

Digital Electronics is a core subject in engineering education that introduces students to the operation of digital systems, particularly sequential circuits such as shift registers. In practice, shift registers are widely used in data storage, data transfer, and signal processing applications. Despite their importance, many students find it challenging to fully understand how data moves within these systems, especially when dealing with different configurations such as Serial-In Serial-Out (SISO), Serial-In Parallel-Out (SIPO), Parallel-In Serial-Out (PISO), and Parallel-In Parallel-Out (PIPO).

One of the main challenges in learning shift register concepts lies in the abstract nature of data movement, which occurs sequentially based on clock signals. Students are often required to interpret timing diagrams and predict output states, which can be difficult without clear visualization. Previous studies in engineering education have highlighted that students tend to struggle with topics involving dynamic processes and temporal changes, particularly when learning relies heavily on static diagrams and theoretical explanations [1]–[3].

In many classrooms, teaching approaches still focus on conventional methods such as lectures and board-based explanations. While these methods are useful for introducing basic concepts, they are often insufficient in helping students develop a deeper understanding of how digital systems operate in real time. As a result, students may rely on memorization rather than conceptual understanding, which affects their ability to apply knowledge in problem-solving situations [4]–[6].

This issue is further supported by findings from Continuous Quality Improvement (CQI) analysis, where students consistently show lower performance in the knowledge domain (CLO1) compared to practical and analytical domains. Although students are able to complete laboratory tasks, their understanding of underlying concepts, particularly in sequential circuits, remains limited. Similar patterns have been reported in previous studies, where a gap exists between theoretical understanding and practical application in engineering education [7]–[9].

To overcome these challenges, recent research has emphasized the importance of visualization and hands-on learning in improving student understanding. Interactive learning tools, simulation environments, and physical teaching aids have been shown to enhance engagement and support conceptual learning, especially for topics involving dynamic system behaviour [10]–[12]. In particular, real-time visualization allows students to observe system responses directly, making abstract concepts more concrete and easier to understand.

In line with this approach, this study proposes an interactive teaching and learning method that integrates visualization and hands-on learning using a shift register trainer kit. The proposed approach enables students to observe real-time data movement and directly compare different register operations, including SISO, SIPO, PISO, and PIPO. By linking theory with direct observation, the approach aims to improve conceptual understanding and reduce students' reliance on memorization.

2.0 METHODOLOGY

This study uses a quantitative approach with a one-group pre-test and post-test design to evaluate the effectiveness of the proposed teaching method. The approach was implemented directly during laboratory sessions, based on the actual teaching practice in the Digital Electronics course. The focus of the implementation was to help students understand shift register concepts through a combination of simple explanation and hands-on activity.

An interactive shift register learning kit was developed to support the teaching process, particularly for SISO, SIPO, PISO, and PIPO operations. The system was designed using a 4-bit configuration with basic components such as input switches, control buttons, and LED indicators. During the session, students were able to set their own input data and observe how the data moves from one stage to another based on the clock signal. The LED display made it easier for students to see what actually happens inside the circuit, instead of just imagining it from diagrams. This type of visual support is important, especially for topics that involve sequential changes over time, which are often difficult for students to follow using conventional methods alone [10], [11].

The teaching session was conducted in two parts. At the beginning, students were given a brief explanation of the basic concept of shift registers, focusing on how data moves and how different modes operate. The explanation was kept simple to avoid overloading students with theory. After that, students were directly involved in using the learning kit. They were asked to try different input combinations, control the clock, and observe the output changes. Through this activity, students could clearly see the difference between serial and parallel data transfer. This hands-on experience helped them relate what they learned in theory to what they observed in practice, which is known to improve understanding and engagement in engineering education [12], [13].

To measure the effectiveness of the approach, a pre-test and post-test were conducted using Google Forms. The tests consisted of 20 objective questions related to shift register concepts. The pre-test was given before the learning activity to identify the students' initial understanding, while the post-test was conducted after the session to see whether there was any improvement. The use of an online platform helped in collecting the data more systematically and reduced errors in recording student responses.

The overall procedure followed a simple sequence, starting with the pre-test, followed by explanation, hands-on activity, and finally the post-test. This structure allowed students to go through the full learning process, from initial exposure to actual application. Similar structured approaches have been reported to be effective in improving conceptual understanding, especially when combined with active learning strategies [14], [15].

The data collected from both the pre-test and post-test were analyzed using descriptive statistical methods. The analysis focused on comparing the mean scores before and after the implementation of the learning activity, in order to observe any improvement in students' understanding. In addition, the percentage improvement in student performance was calculated, together with a comparison across the three programmes involved in the study. The percentage improvement in student performance was calculated using Equation (1):

$$\text{Improvement (\%)} = \frac{\text{Post-Test} - \text{Pre-Test}}{\text{Pre-Test}} \times 100 \quad (1)$$

This method of analysis provides a clear and straightforward way to evaluate the effectiveness of the proposed teaching approach in improving students' understanding of shift register concepts. Apart from test performance, students' perceptions towards the proposed learning approach were also evaluated using questionnaire responses. The analysis of the questionnaire was carried out by calculating the mean score for each item, which provides an overall indication of student acceptance, engagement, and perceived understanding during the learning session.

3.0 RESULT

The effectiveness of the proposed teaching approach was evaluated was evaluated based on the comparison between pre-test and post-test results collected from students across three programmes, namely DEU, DJK, and DEP. The detailed performance of each programme is illustrated in Fig. 1, Fig. 2, and Fig. 3, while the overall summary is presented in Table 1.

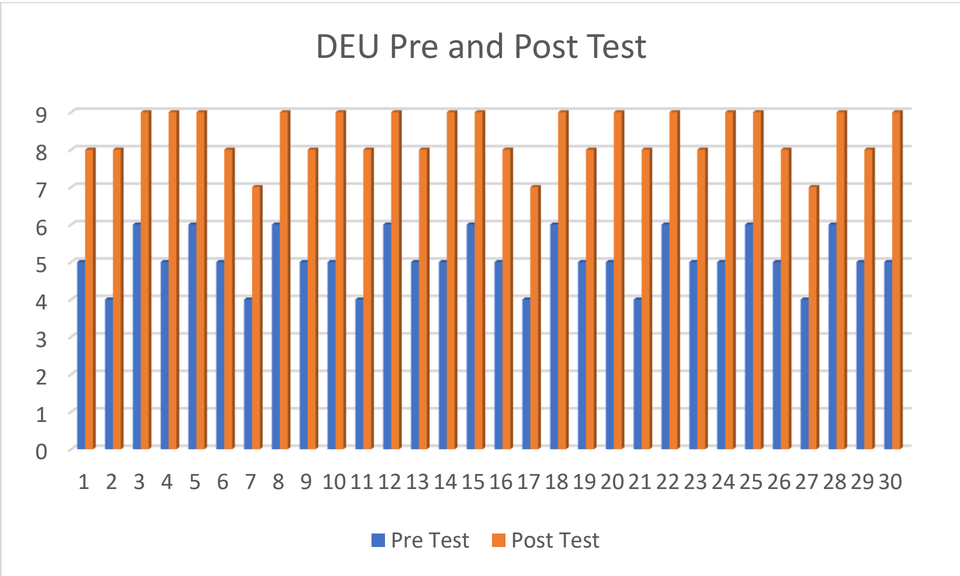

Fig. 1. Pre-Test and Post-Test Scores for DEU Students

Table 1. Pre-Test and Post-Test Performance

Program	Pre-Test (Mean)	Post-Test (Mean)	Improvement (%)
DJK	5.3	8.3	56.6
DEU	5.1	8.5	66.7
DEP	5.0	8.2	64.0
Overall	5.13	8.33	62.4

Referring to Table 1, the overall mean score increased from 5.13 in the pre-test to 8.33 in the post-test, which represents an improvement of 62.4%. This shows a clear positive impact of the proposed teaching approach on students' understanding of shift register concepts. The increase in mean score indicates that students were able to grasp the concepts more effectively after being exposed to the combination of explanation and hands-on learning.

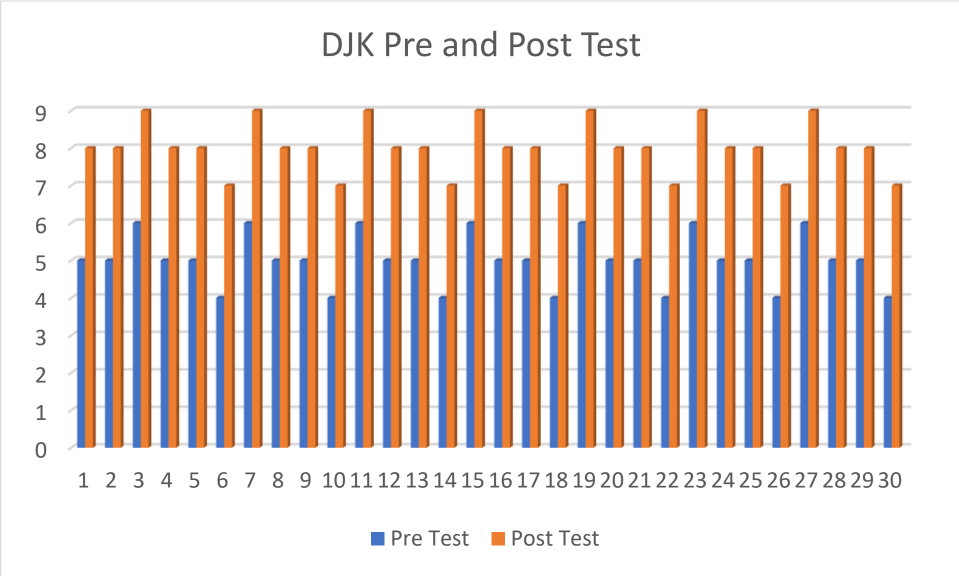

Fig. 2. Pre-Test and Post-Test Scores for DJK Students

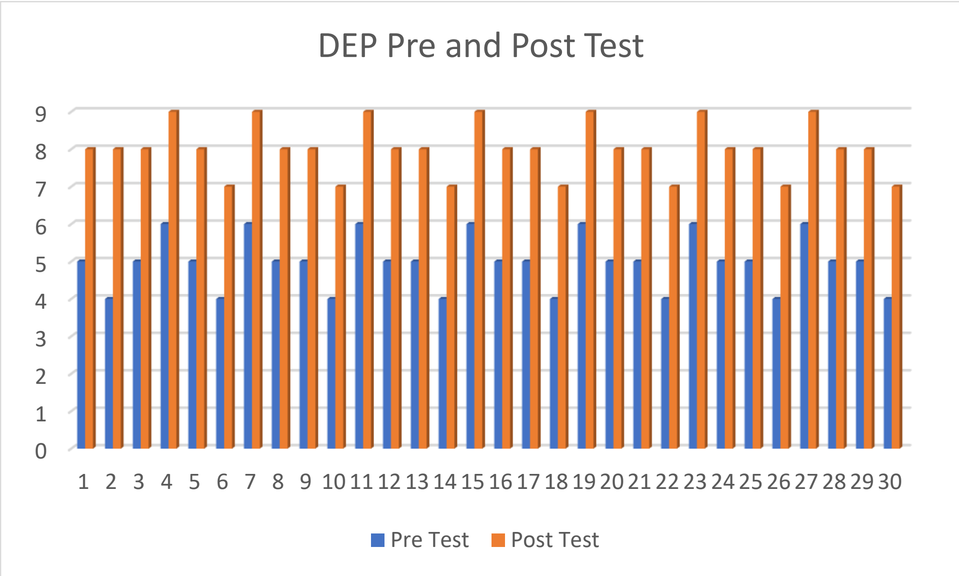

Fig. 3. Pre-Test and Post-Test Scores for DEP Students

A more detailed observation can be made based on each programme. As shown in Fig. 1, students from the DEU programme demonstrate a consistent increase in performance, where almost all students achieved higher scores in the post-test compared to the pre-test. The mean score for DEU increased from 5.1 to 8.5, with an overall improvement of 66.7%, which is the highest among the three programmes. The pattern in the graph clearly shows that the majority of students improved by at least two to four marks.

For the DJK programme, the trend observed in Fig. 2 also indicates a positive improvement. Although the increase is slightly lower compared to DEU, the overall pattern remains consistent. The mean score increased from 5.3 to 8.3, resulting in an improvement of 56.6%. Most students show a steady increase in their scores, suggesting that the approach is still effective even though the level of improvement varies.

Similarly, Fig. 3 presents the performance of students from the DEP programme. The results show a clear upward trend, where most students achieved higher post-test scores. The mean score increased from 5.0 to 8.2, which represents an improvement of 64.0%. This indicates that the learning approach is also effective for this group of students.

From the three figures, it can be observed that the improvement is not limited to a small number of students, but occurs across almost the entire group. This consistency is important, as it shows that the approach does not only benefit high-performing students but also helps those who initially had a weaker understandings.

One of the key observations during the session was that students responded well to the visual representation provided by the learning kit. The LED display allowed them to see how data moves within the shift register in real time, which made it easier to understand the difference between SISO, SIPO, PISO, and PIPO operations. This is particularly helpful for students who previously struggled to interpret timing diagrams and data flow using static representations.

In addition, the hands-on activity encouraged students to actively engage with the learning process. Instead of passively receiving information, they were involved in setting input data, controlling the clock signal, and observing output changes. This interaction helped them connect theoretical concepts with actual circuit behaviour, which explains the improvement observed in the post-test results.

Overall, the results presented in Fig. 1, Fig. 2, Fig. 3, and Table 1 clearly show that the proposed approach has a positive impact on student understanding. The combination of simple explanation and hands-on learning provides a more effective way for students to learn shift register concepts compared to conventional teaching methods.

4.0 CONCLUSION

This study explored the use of an interactive teaching approach to improve students' understanding of shift register concepts in Digital Electronics. Based on the results obtained, it is clear that the combination of simple explanation and hands-on learning has a positive impact on students performance. The improvement in mean score from 5.13 to 8.33 shows that students were able to better understand how data moves within the system, particularly when they were given the opportunity to observe and interact with the learning kit.

One important finding from this study is that visualization plays a key role in helping students understand abstract concepts. When students are able to see how data shifts in real time through LED indicators, it becomes easier for them to differentiate between SISO, SIPO, PISO, and PIPO operations. This reduces their dependence on memorization and allows them to explain the concept more confidently.

In addition, the hands-on activity helped to increase student engagement during the learning session. Students were more involved in the process, which made the learning experience more meaningful compared to conventional lecture-based methods. This is particularly important in engineering education, where understanding is often developed through practice rather than theory alone.

The findings of this study also support the issues identified in the CQI analysis, where students tend to show weaker performance in conceptual understanding. By introducing a simple and practical teaching aid, the gap between theory and practice can be reduced. This suggests that even a basic learning tool can make a significant difference if it is used in the right way.

Overall, the proposed approach provides a practical alternative for improving the teaching and learning of shift register concepts, especially in TVET institutions. Future work can focus on improving the design of the learning kit and extending its use to other topics in digital electronics. This study highlights that simple and low-cost teaching aids can significantly improve conceptual understanding when combined with appropriate teaching strategies.

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