Tracking Students' Learning Progress on Troubleshooting Logical Circuits Using Web Application

Barish Yumerov [1], Galina Ivanova [1]

[1]*University of Ruse "Angel Kanchev", Studentska 8, Ruse, Bulgaria*

Abstract **– This paper presents the development and usage of a web application for troubleshooting logical circuits. The application is designed to support the teaching and learning of troubleshooting logical circuits by providing students with a platform to practice troubleshooting and allowing teachers to monitor students' progress. The web application features an interactive interface that allows students to simulate and troubleshoot logical circuits using the method of truth table. The application also provides students with immediate feedback on their troubleshooting attempts and highlights areas that need improvement. Furthermore, the application has a tracking system that allows instructors to monitor students' progress and identify areas where students may need additional support. Growing complexity and usage of logical combinational circuits require better methods for teaching and improving students' engagement.**

Keywords **– Web application, students' engagement, combinational circuits, MVC architecture, students' feedbacks.**

DOI: 10.18421/TEM123-12
https://doi.org/10.18421/TEM123-12

Corresponding author: Barish Yumerov,
University of Ruse "Angel Kanchev", Studentska 8, Ruse, Bulgaria
Email: byumerov@uni-ruse

Received: 15 April 2023.
Revised: 18 July 2023.
Accepted: 25 July 2023.
Published: 28 August 2023.

1. Introduction

In recent years, the field of electrical and electronics engineering has witnessed significant advancements with the integration of digital logic circuits. However, as these circuits continue to grow in complexity, students face challenges in comprehending their functionalities and troubleshooting them [8]. Traditional teaching methods, such as theoretical lectures and physical circuit building, have limitations in effectively enhancing students' understanding and problem-solving abilities in the realm of digital circuits [10].

Web-based applications can be utilized to address these limitations and improve the learning experience for students [11]. Such applications can provide a platform for interactive and hands-on learning, allowing students to simulate circuits and also track their learning progress [5], [6], [7].

In this paper, a web application that allows students to troubleshoot logical circuits and monitor their progress throughout their learning journey is presented.

The proposed application has a user-friendly interface that allows students to simulate digital circuits and troubleshoot them by manipulating different inputs and outputs. The application also provides real-time feedback and tracks students' mistakes, enabling students to visualize the circuit's operation and identify potential issues. Moreover, the application will keep track of the students' learning progress by recording their performance on each circuit and providing personalized feedback based on their strengths and weaknesses.

In the system each circuit is presented as a single or multiple Boolean functions. On each circuit the application generates random malfunctions that students should detect via analyzing inputs and outputs of the respective circuit.

The proposed web application holds great potential as a valuable tool for enhancing students' understanding and problem-solving abilities in the field of digital logic circuits.

It has the potential to transform the way digital circuits are taught, providing a more engaging and interactive learning experience that can lead to improved student outcomes.

2. Web Application Architecture

The architecture of the web application was chosen based on research which has multiple key factors:

- Functionality and Features: The key factors that must be considered when selecting a web application is its features and functionality. The architecture must allow the features that align with applications' business objectives and goals. It should also provide an easy to use interfaces, navigation, and usability.

- Scalability: A good web application should be scalable and able to handle an increased workload or traffic.

- Security: Security is a key factor that must be considered when selecting a web application. The application must have security features like encryption, authentication, and authorization. It should also comply with industry regulations and standards like the General Data Protection Regulation (GDPR).

- Integration: The web application must be able to integrate with other systems or applications that are used. Integration with other systems will help maintenance, save time and increase productivity.

- Performance: A web application's performance must be considered before selection so that it is able to handle the required load, data volume and provide quick response times. It should also be reliable and available 24/7.

- Support and Maintenance: A web application requires an architecture that allows easy maintenance, upgrade and update upon feedbacks and system growth.

- Cost: Cost is also an important factor to consider when selecting a web application architecture. The cost should be justified and aligned with the budget.

Taking into account the factors above, the architecture that fits our needs most was MVC using C# and OIDC for authentication.

The Model-View-Controller (MVC) [3] architecture is a design pattern used to separate an application into three interconnected parts: the Model, View, and Controller, as presented in Figure 1.

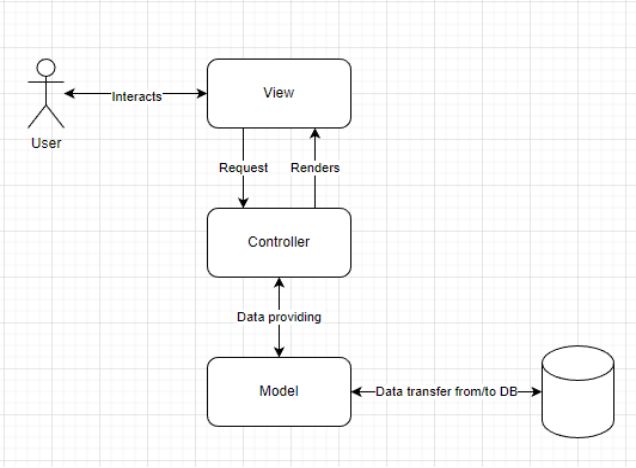

Figure 1. MVC Architecture

Model: This component represents the application's data and business logic. It interacts with the database, APIs, or any other data sources to retrieve and manipulate data. The Model component is responsible for the data validation, business logic, and data storage of the application.

View: The component represents the user interface of the application. It displays the data to the user and collects input from the user. The View component is designed and programmed using various technologies like HTML, CSS, and JavaScript.

Controller: This component acts as an intermediary between the Model and View components. It receives input from the user, interacts with the Model component to retrieve and manipulate data, and then updates the View component to display the updated data to the user. The Controller component also handles the application's navigation and manages the communication between the Model and View components.

The primary advantage of using MVC architecture is its promotion of separation of concerns. By dividing an application into three distinct components Model, View and Controller, it becomes easier to develop, maintain, and test each component independently.

The MVC architecture also makes the application more modular and extensible, allowing developers to add new features without affecting the existing code.

OIDC (OpenID Connect), is a protocol that is commonly used for authentication in modern web applications. There are multiple reasons why OIDC is a popular choice for authentication [9]:

Secure and Robust: OIDC [4] is built on top of OAuth 2.0, which provides a secure and robust authentication framework. It uses a standard cryptographic algorithms and protocols to ensure that user authentication information is transmitted securely and cannot be intercepted by unauthorized parties.

User-Friendly: OIDC offers a user-friendly authentication experience. It supports social identity providers like Google, Facebook, LinkedIn and many more, which allows users to easily authenticate with their existing accounts. It also supports single sign-on, which means that once a user has authenticated with one application, they do not need to re-enter their credentials when accessing other applications that use the same OIDC identity provider.

Standardized: OIDC is an open standard that is widely adopted by many authentication providers, making it easy to integrate with different platforms and services.
This standardization also helps to ensure that OIDC-compliant systems are consistent and can work together seamlessly.

Scalable: OIDC is designed to be scalable, making it suitable for use in large-scale applications. It uses a token-based authentication mechanism, which is lightweight and does not require a lot of overhead. This makes it possible to authenticate large numbers of users quickly and efficiently.

Overall, OIDC is a secure, user-friendly, standardized, and scalable authentication protocol that is widely adopted in the industry. It offers many benefits for both developers and end-users, making it a popular choice for authentication in modern web applications.

In Figure 2 is described how any client can use code flow to retrieve a token from the OIDC identity provider. Once the token is fetched, the client can use it to authenticate itself to any microservice that supports this type of authorization.

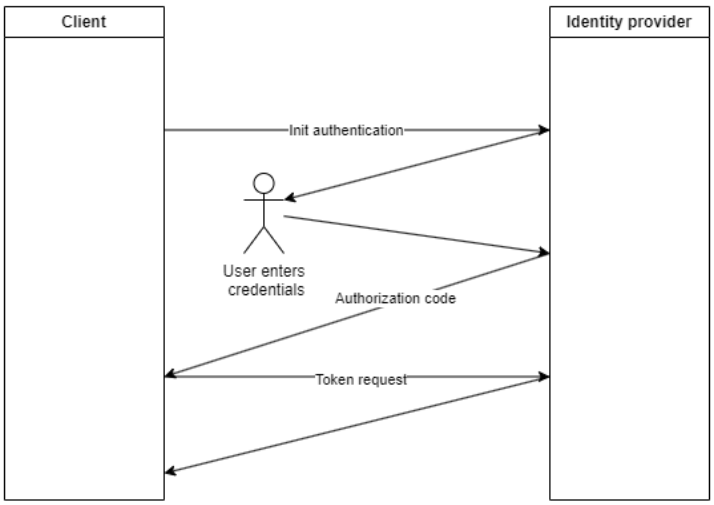

Figure 2. OIDC Authentication code flow.

3. Studying Students' Progress and Behavior

In this paper students' progress is being studied by comparing conventional teaching using notebooks versus more modern way – using web application in class.

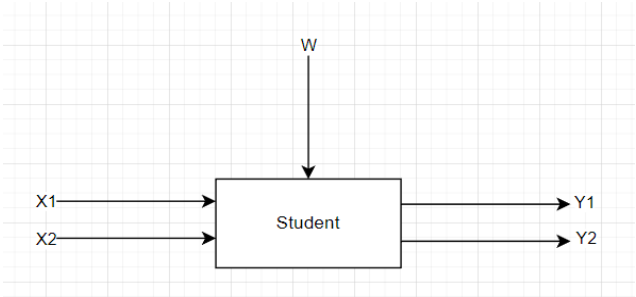

Figure 3. Studying students' behavior

In Figure 3, it is depicted how a student is being studied:

- X_1 – Tasks that students resolve using conventional approach;
- X_2 – Tasks that students resolve using web application;
- Y_1 – Students' results and progress of solving tasks using conventional approach;
- Y_2 – Students' results and progress of solving tasks using web application;
- W - Preliminary preparation of the student in the subject and other external influences and factors.

The approach of comparing conventional teaching against using interactive web application was selected after doing a research and concluding the benefits of using such technique [1]. Some of the advantages are:

- Web applications can provide real-time feedback on student's progress, which can be helpful for both the teacher and the student The teacher can use a web application to quickly grade an assignments, and students can see their scores and feedback instantly. This allows students to identify their strengths and weaknesses and work on improving them;
- Web applications can offer more personalized learning experiences. With the ability to track student progress and performance data, teachers can tailor their teaching methods and materials to better suit each student's individual needs. This can result in improved learning outcomes and better engagement from students;
- Web applications can make it easier to collaborate and communicate with students. Teachers can use web applications to share study materials, assignments, and feedback with students in real-time. Students can also use web applications to collaborate on projects and communicate with their teachers and peers.

Studying student progress using web applications in class can be more efficient, effective, and engaging than the conventional way of using paper and pen. By leveraging technology, teachers can provide more personalized learning experiences, real-time feedback, and better collaboration opportunities for their students.

4. Analysis and results

Students' progress on discipline "Reliability and diagnostics of computer systems" in University of Rousse is analyzed by studying student's in class and homework results using multiple factors:

- Time per task;
- Number and type of mistakes per task depending on task complexity;
- Students' engagement

Time per task: Using web applications in education can significantly reduce the time per task for students. With the help of web applications, students can easily access learning materials, submit assignments, and receive feedback from teachers, all without having to physically go to the classroom or meet with the teacher in person.

Moreover, the used web applications often have features that can automate certain tasks, such as grading assignments, which can significantly reduce the time that teachers spend on grading or supporting students via interactive interface, which also reduces time per assignment and supports teachers in their work [2]. This also means that students can receive feedback on their work much faster than with the conventional paper and pen method.

In the figure below using bar chart, the web system used in classes generates average time per task that is required for a student to complete assignments.

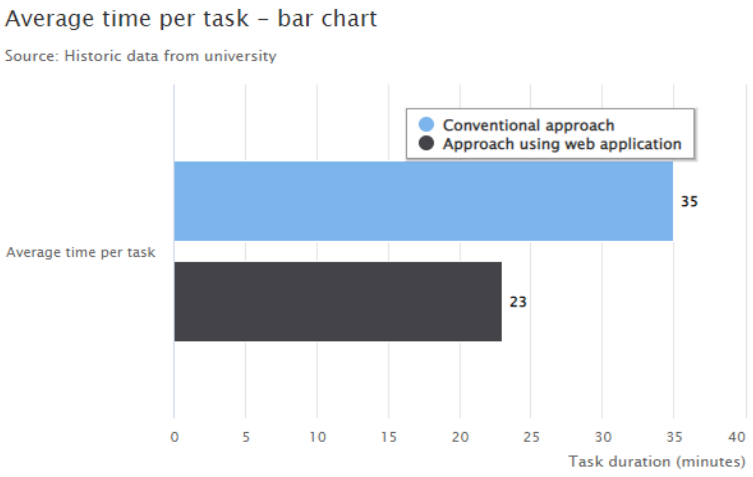

Figure 4. Time per task chart

By analyzing the chart above conclusion can be made that the use of web applications in education helps students to be more productive which can lead to more efficient learning and better academic outcomes.

Number of mistakes per task: While using the web application in discipline “Reliability and diagnostics of computer systems” the number of mistakes made by students in their class assignments reduce, even on more complex tasks. This is because a web application can provide various features and benefits that are not available in traditional paper-based assignments.

The web application provides instant feedback to students, which helps them identify and correct mistakes as they work through the assignment. If a student enters an incorrect answer, the web application immediately flags it as incorrect and provides the correct answer and an explanation of the mistake. This helps students learn from their mistakes and avoid making the same errors in future.

It also provides an interactive and engaging learning experience that helps students understand the concepts and topics better by providing videos, animations and other interactive simulations to explain complex problems.

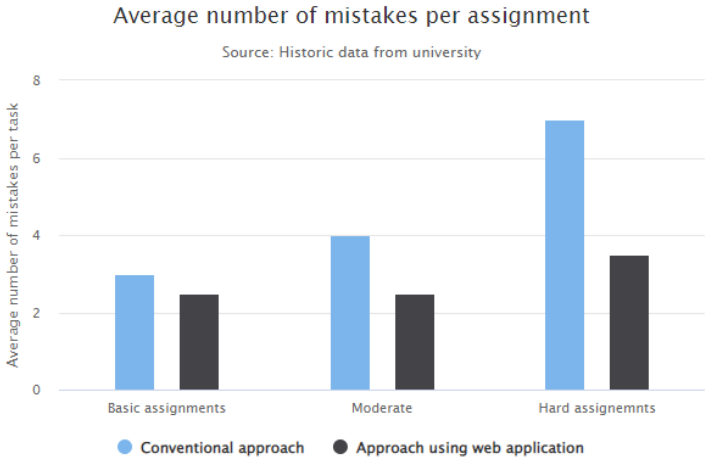

Figure 5. Average number of mistakes per task complexity

In Figure 5. is noticeable that using web application in class is reducing the number of mistakes per assignment. The difference is most noticeable in more complex assignments due to multiple factors as: number of solved tasks using web application is much greater because it takes less time solving problems and the system also supports students with some initial configurations that students have to do manually on paper.

Student’s engagement: Surveys was conducted on students who have participated in interactive learning using the web application on multiple topics such as: engagement, learning material clarity, interactiveness, workflow, etc. After analyzing the survey across all students conclusions on multiple points can be made:

- web applications boost students engagement by providing a more dynamic and interactive learning environment;
- engagement is provided by the immediate feedback on students progress;
- home based or remote students are not excluded from education and are included in learning processes.
-

5. Web Application Implementation

The web application for troubleshooting combinational circuits was planned and implemented by following most of the principles and requirements described in this paper.

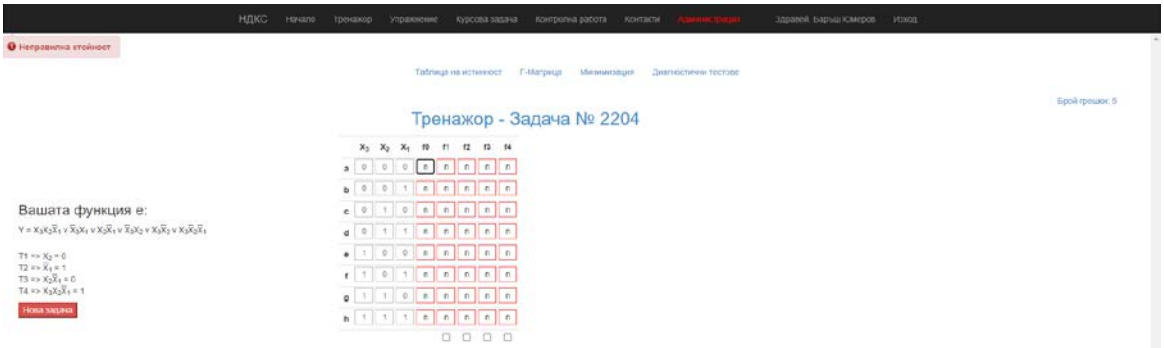

Figure 6. Web application in training mode

In Figure 6 it is displayed how a student troubleshoots a single circuit with four malfunctions using the truth table method in training mode. When a mistake is made the system indicates it and gives hints.

The web application is also a tool for supporting teachers that generates random tasks for students including the solution for it, or the teacher can manually input a task and just generate the solution for it. This can be observed in Figure 7.

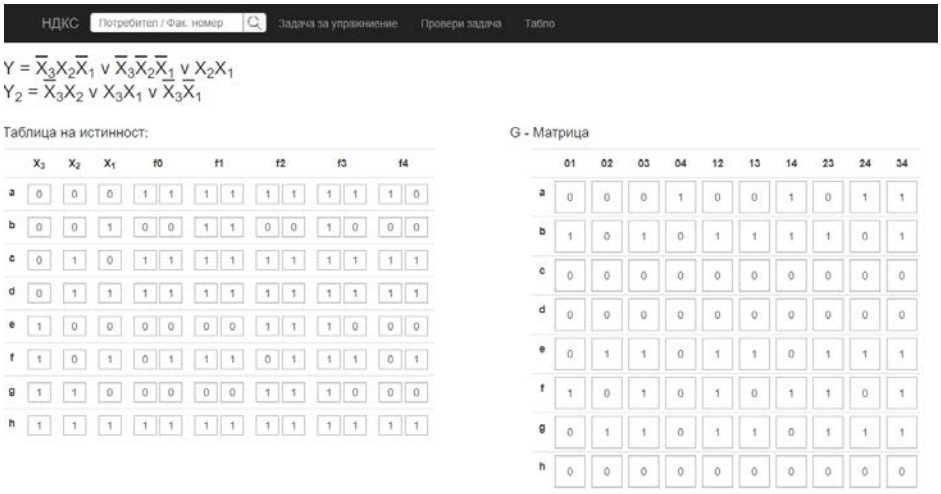

Figure 7. Generating random task and solution for two combinational circuits

The web application has a build in dashboard that generates charts based on students' achievements. This allows teachers to monitor students' progress almost in read time, which allows in time reaction and improvement of the teaching process.

An example of a dashboard chart depicting number of completed tasks done by students by type using bar chart is in Figure 8.

Figure 8. Number of tasks completed by type

6. Conclusion

The integration of web applications into the classroom has revolutionized the learning experience for students. The use of web applications has improved students' engagement in class, making learning more interactive, dynamic and fun. Students can spend less time on tasks such as note-taking, as web applications provide easy navigation and quick access to information.

The web application use provides instant feedback and tracking progress, which motivates students to continue learning and improve their skills. This personalized feedback helps students adjust their learning strategies accordingly, thus enhancing their learning outcomes.

The interactive system also provides a means for conducting surveys and polls, enabling teachers to gather information about student understanding and tailor their teaching accordingly.

Additionally, web applications can accommodate students with different learning styles and abilities, making learning more accessible and inclusive for all.

Conducting surveys on students across years show increased engagement and performance in students. An analyzes of multiple survey results shows improved feedback from students on all topics – design, ease of orientation, application speed, solution guide, algorithm description and practicing and consolidating skills. Regular surveys contribute to faster and on time feedback, so that required improvements are applied to the system sooner.

The web application system mentioned in this paper has been integrated into the learning process and has provided numerous benefits for students, including improved engagement, time-saving, and ease of navigation, personalized feedback, and inclusive learning experiences. It is evident that web applications will continue to play a significant role in the classroom as technology continues to advance, and educators should explore the numerous ways in which they can use web applications to enhance the learning experience for their students.

Tracking student's learning progress helps teachers identify areas of weakness in their students' understanding of the material. By monitoring student engagement and progress, teachers can identify students who may be consistently falling behind or not making sufficient progress. This valuable information can be used to target specific areas for improvement and provide additional support to students. Using such web application in the educational process teachers can personalize the learning experience. They can tailor the curriculum to meet the individual needs of each student and adjust the pace of learning ensuring that students are appropriately challenged without feeling overwhelmed. Additionally, by tracking student's progress over time, teachers can assess the effectiveness of their teaching methods and determine whether students are achieving the desired learning outcomes.

References:

[1]. Veluvali, P., & Surisetti, J. (2022). Learning management system for greater learner engagement in higher education—A review. *Higher Education for the Future*, *9*(1), 107-121.

[2]. Terrin, É., & Triventi, M. (2023). The effect of school tracking on student achievement and inequality: A meta-analysis. *Review of Educational Research*, *93*(2), 236-274.

[3]. Selfa, D. M., Carrillo, M., & Boone, M. D. R. (2006). A database and web application based on MVC architecture. In *16th International Conference on Electronics, Communications and Computers (CONIELECOMP'06)*, 48-48. IEEE.

[4]. Mainka, C., Mladenov, V., Schwenk, J., & Wich, T. (2017). SoK: single sign-on security—an evaluation of openID connect. In *2017 IEEE European Symposium on Security and Privacy (EuroS&P)*, 251-266. IEEE.

[5]. Widyaningsih, S. W., Yusuf, I., Prasetyo, Z. K., & Istiyono, E. (2020). Online interactive multimedia oriented to HOTS through e-learning on physics material about electrical circuit. *JPI- Jurnal Pendidikan Indonesia*, *9*(1), 1-14.

[6]. Altalbe, A. A. (2019). Performance impact of simulation-based virtual laboratory on engineering students: A case study of Australia virtual system. *IEEE Access*, *7*, 177387-177396.

[7]. Zlatarov, P., Ivanova, G., & Baeva, D. (2019). A web-based system for personalized learning path tracking of doctoral students. In *2019 42nd International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO)*, 773-778. IEEE.

[8]. Aliev, Y. I., Borodzhieva, A. N., & Ivanova, G. I. (2018). Software System for Simulation Research of Reed-Solomon Decoders in Presence of Noise Applied in Digital Communication Systems. In *2018 IEEE 24th International Symposium for Design and Technology in Electronic Packaging (SIITME)*, 31-36. IEEE.

[9]. Yumerov, B., & Ivanova, G. (2020). OIDC Authentication for Educational Purposes and Solving Problems for Localization of Faults in Combinational Circuits. In *Proceedings of 4th Computational Methods in Systems and Software 2020*, *1*(4), 419-429. Springer International Publishing.

[10]. Santally, M. I., & Senteni, A. (2013). Effectiveness of Personalised Learning Paths on Students Learning Experiences in an e-Learning Environment. *European Journal of Open, Distance and E-learning*, *16*(1), 36-52.

[11]. Atanasov, V. T., & Ivanova, A. S. (2019). A framework for measurement of interactivity of digital learning resources. In *2019 42nd International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO)*, 649-654. IEEE.