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Preliminary Experience and Impact of Experiment-focused Teaching Approach in a Computer Architecture Course in Computer Science

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Preliminary Experience and Impact of Experiment-focused Teaching Approach in a Computer Architecture Course in Computer Science

Abstract—One of the key knowledge areas in Computer Science (CS) is Digital Logic and Computer Architecture where the learning outcome is an understanding of Boolean algebra, logic gates, registers, or arithmetic logic units, etc. and explaining how software and hardware are related to a computing system. Experimental Centric based Instructional Pedagogy (ECP) with portable laboratory instrumentation might provide real hands-on experience to obtain a practical understanding of those concepts at a lower cost compared to virtual hands-on laboratories that lack direct interaction with real apparatus or no integration of labs in the course. This work presents the initial adaptation of ECP to introduce the fundamentals of digital logic concepts in a Computer Architecture course in Spring 2022 for the first time in a CS department at a university teaching such courses without a lab and serving predominantly minority students. To establish a conducive and dynamic classroom environment by discovering course content through exploration, students majoring in CS were introduced to several logic gate types, worked with breadboards to connect circuits, and carried out operations to produce the necessary output using the commercial ADALM 1K Active Learning Module. To evaluate the impact of the ECP on students' performance in the class, three different evaluation methods were used, such as classroom observation, a signature assignment, and a Motivated Strategies for Learning Questionnaire (MSLQ) survey. The Classroom Observation Protocol for Undergraduate STEM (COPUS) findings indicated greater student engagement when ECP is used; the Signature assignment results indicated improved learning outcomes for students; and the MLSQ survey, which measures students' motivation, critical thinking, curiosity, collaboration, and metacognition, determined a positive impact of the ECP on the CS participants.

Keywords –CS education, active learning, experimental centric learning, collaborative learning, project based learning, retention.

Introduction

Several critical factors influence student performance, including motivation, self-efficacy, values, curiosity, and, most importantly, learning environments. Learning is a cognitive phenomenon that differs from person to person. There is no doubt, however, that learning through hands-on experience is an effective method of retaining information. Undergraduate students in this digital age have grown up with technology and come from an education system that encourages critical thinking, hands-on learning, teamwork, design skills, problem solving, and experiential learning [1]. Most students today are visual and interactive learners, and research in educational theory and cognitive psychology shows that this type of learning is one of the most effective methods for teaching students of all ages how to think and learn. [2-4]. Traditional blackboard-based lecturing styles in our classrooms are insufficient for capturing these students' attention and stimulating their interests. Instead of lecturing for the duration of a class, instructors can create a positive learning experience for students by using appropriate teaching strategies and creating a conducive and dynamic classroom environment. This allows students to see the results of their work right away, including any errors that were reported, and allows them to make adjustments right away. Early childhood researcher Jean Piaget For example, Jean Piaget, an early childhood researcher, demonstrated in the early 1900s that children learn better if they are led through a series of activities rather than just presented with facts [2]. Meyers and Jones state in their seminal book on active learning [3] that learning is by nature an active endeavor and that different people learn in different ways. Active learning enforces these assumptions by getting students active. Active learning can be reading, writing, discussing, solving a problem, or responding to questions that require more than factual answers

Furthermore, several studies have found that technology-based projects and hands-on learning, similar to experimental centered instructional pedagogy (ECP), can be used to help students better understand the relationship between theory and practice when working on engineering-related projects. [5-8]. Using hands-on mobile multi-function activities, ECP integrates problem-based activities and a constructivist instructional approach. This pedagogy gives students more freedom to learn at their own pace in a variety of settings without the need for old-fashioned and bulky laboratory instruments that are time- and space-limited. Students can easily use the new portable laboratory equipment to improve their hands-on skills by collaborating with peers and practicing outside of the classroom. For instance, in a study of 13 historically black colleges and universities (HBCUs), [9] Using hands-on mobile multi-function activities, ECP integrates problem-based activities and a constructivist instructional approach. This pedagogy gives students more freedom to learn at their own pace in a variety of settings without the need for old-fashioned and bulky laboratory instruments that are time and space limited. Students can easily use the new portable laboratory equipment to improve their hands-on skills by collaborating with peers and practicing outside of the classroom. For instance, in a study of 13 historically black colleges and universities (HBCUs), In recent years, the lack of diversity in computing fields in the United States has been the subject of a number of discussions, including those in technology, companies, media, government, and academia. Computer science (CS) is one of the fastest-growing and highest-paying fields. African Americans are thought to be underrepresented in CS [12]. According to federal data [13], only 8.9% of the more than 71,000 bachelor's degrees awarded in this field in 2017 went to black students, and only 10.1% went to Latino students, which is significantly lower than the percentages of black and Latino people in the US, which are 13.4% and 18.5%, respectively. According to IPEDS data from the National Center for Education Statistics (NCES) (CRA, 2017), people from underrepresented groups in computing accounted for nearly 18% of all CS bachelor's degrees awarded for the majority of the years 2007–2015 [14]. This underrepresentation is particularly noticeable in the CS industry and academic employment sectors. Given the low representation of African Americans in computing, numerous interventions and strategies in computer science education have been implemented to intentionally increase the representation of black students. Retention issues must be addressed if computing diversity is to be increased. A report published by the Association for Computing Machinery (ACM) [15] identifies diversity gaps in computer science and makes a number of recommendations to improve retention rates for underrepresented minorities in CS programs, such as incorporating collaboration and team-based learning and adopting pedagogical strategies to ensure that all students perceive classrooms and labs as welcoming environments.

Motivated by previous successes in both engineering and STEM fields, we intend to expand the implementation and evaluation of ECP on underrepresented CS undergrads' motivation, curiosity, and attitudes toward learning. The preliminary results of the development, implementation, and expansion of ECP in a Computer Architecture course in CS using a portable hardware platform are presented in this paper (the Analog Discovery instrumentation board). The first cohort of this newly redesigned course began in the spring of 2022. In conjunction with the implementation of classroom observation protocols that measure active learning during course instruction, quantitative and qualitative data on key constructs of student success were collected. According to anonymous research data collected from this cohort of the revised course, the redesign with ECP improved overall course reviews while meeting educational goals of introducing students to core knowledge areas in digital logic and computer architecture.

This research expands on the primary research question, "Whether the inclusion of ECP-based laboratory experiences in the Computer Architecture course improves student learning, motivation, and curiosity in CS?" Robust statistical analysis is used to answer the question by measuring key constructs associated with student success, such as motivation, identity, and self-efficacy. The Motivated Strategies for Learning Questionnaires (MSLQ) [16] and the Litman and Spielberger curiosity assessment instruments [17] are used to determine course evaluations and measurements of cognition, engagement, and motivation, which are supplemented with specifically designed additional items or measures to capture the project's intervention.

The findings show a significant difference between the pre- and post-tests on several MSLQ key constructs related to student success. When ECP is implemented, the results of the signature assignment show an increase in students' learning outcomes, and the results of the Classroom Observation Protocol for Undergraduate STEM (COPUS) show more active student engagement

Literature review

Digital Logic and Computer Architecture/Organization Related Courses are important knowledge areas in CS because they help students understand the logical design and implementation of digital circuits and microprocessors from an engineering standpoint. These courses are typically designed so that students gain theoretical knowledge of the computer's internal structure and components, as well as how instructions are executed and handled by various architectures. Topics covered include Boolean algebra, combinational circuits, sequential circuits, finite state machine design, processor pipelines, and memory hierarchy. Instruction is typically delivered in a laboratory setting using computer system simulators to provide students with a hands-on understanding of the topics covered in class. These simulators are frequently used to help students understand complex technologies that are difficult to conceptualize and visualize without the help of graphical animations that modern simulators can provide. This hardware-focused course is offered as a major requirement as part of the four-year undergraduate CS degree program. According to studies, CS students generally show a lack of interest in these courses because their preference is for programming and software-oriented courses [18]. It is also due to the enormous gap caused by the increasing number of abstraction layers interposed between real hardware and end-user-oriented applications. As a result, motivating students and generating interest in hardware courses has always been a challenge for course instructors [19]. It has been scientifically proven that students often do less than what teachers expect in computer architecture courses [20].

Traditional hands-on laboratories might provide an opportunity for students to practice these skills through conducting experiments and data analysis. Hands-on laboratory experience strengthens students' ability to understand the fundamental concepts by effectively implementing a hardware system to attain the set objectives for the activity. Examples of such laboratories are those at the Colorado University campus in Boulder [21] and at Auburn University [22]. Teaching hardware using extensive hands-on experience relies on the availability of hardware platforms to support these design activities [23]. However, the downside is that laboratories are very expensive to operate in terms of facilities, resources, and staff time, which makes them unaffordable for a CS department, where more emphasis is put on mainly software-related courses. Given this reality, new and innovative approaches are required to enhance access and learning in low-resource settings. New technologies, such as virtual and remote laboratories, provide opportunities for students to conduct experiments while substantially reducing the costs associated with traditional laboratories. Hence, the traditional approaches to introducing this subject often limit practical work to virtual laboratories in the form of simulation. It allows students to verify their theoretical knowledge from lecture classes by observing and exploring characteristics and actual system behavior. B. Nikolic et al. [24] surveyed and evaluated a variety of simulators available in the open literature and suitable for laboratory use in computer architecture and organization. The first group of simulators, which includes HASE, ISE Design Suite, JHDL, Logisim, M5, Quartus II, Simics, SMOK, and Virtual Vulcan, contains the necessary tools and methods to allow the user to first build specific computer system configurations and then simulate them. The second group of simulators includes tools that allow the user to simulate already created systems, such as ANT, CASLE, CCSTUDIO, CodeWarrior, CPU Sim, DigLC2, DLXview, Easy CPU, EDCOMP, ESCAPE, FastCache, HASE-Dinero, JCachesim, RM, RSIM, SIMCA, SimFlex, SimOS, and SimpleScalar. For example, the authors of [19] present their teaching experiences through hands-on exposure using project-based learning (PBL) by using the simulation tool LOGISIM to impart experiential learning to improve the efficacy of learning concepts of computer organization and architecture. The task entails creating datapaths for arithmetic, logical, data transfer, and branch instructions. Logisim includes a large library of hardware blocks that allow students to design, simulate, and analyze circuits using an intuitive graphical user interface. In [25], the authors design several computer hardware solutions as an experimental project using a single-board computer (e.g., Arduino, Raspberry Pi, etc.). Students are introduced to core computer components early in their coursework and encouraged to study advanced engineering concepts as part of higher-level elective courses to help them better understand the underlying design of hardware modules, with a particular focus on single-board computers and associated hardware modules. These technologies allow students to conduct experiments while significantly lowering the costs associated with traditional laboratories. However, some perceived limitations include a lack of direct interaction with real apparatus, a lack of authentic settings, and computer distraction [14].

With the advancements of experimental-centric and technology-enhanced learning, new opportunities for improving teaching methods and learning quality have emerged in education. Learning mediums and environments, as a result, have evolved over time. Because of their promising capabilities, mobile learning systems have seen increased use in colleges and universities in recent years. Mobile learning is a contemporary method that allows students to learn from anywhere and at any time using mobile devices [26]. When compared to hands-on laboratories, portable hardware platforms can provide real-world experience at a lower cost. The Mobile Studio Board, created a decade ago at Rensselaer Polytechnic University, is an example of a portable hardware platform [8]. It performs functions similar to those of oscilloscopes, function generators, power supplies, and voltmeters. ECP devices are unique in that they can be used in a variety of learning settings, including the classroom for instructor demonstration, the laboratory, and at home. Students are sent home to do their homework. Other versions of the Mobile Studio Board have been developed and are currently in use in universities worldwide, including India, Greece, Austria, Germany, Mexico, and Malaysia. Several research papers [5–11] have found that hands-on learning via mobile studio platforms such as the Mobile Studio Board (MSB) and the Analog Discovery Board (ADB) can help students with diverse learning styles, demographics, and academic backgrounds learn better. There are now several commercial products, such as Analog Devices Inc.'s ADALM 1000 board (ADALM 1K) and ADALM 2000 board (ADALM 2K), Digilent's Analog Discovery 2TM, and Quanser's QUBE-Servo portable platform, that allow students to conduct control engineering experiments.

Given the difficulty, if not impossibility, of obtaining hands-on experience in a traditional lab setting in a CS department, portable hardware platforms could provide a tremendous opportunity to supplement or replace hands-on laboratories. Despite the fact that ECP is widely used in other engineering and STEM disciplines [6, 10–11], our focus is on gaining specific insights into how ECP using a portable device plays out when applied to CS. This paper presents preliminary findings from the development, implementation, and expansion of ECP using the commercial ADALM 1K [27] in a computer architecture course at a university serving predominantly African American students in an urban setting for the first time. The ADALM 1K Active Learning Module is a low-cost learning solution.

Methodology

The goal of this hands-on laboratory experiment is to become acquainted with all fundamental logic gates and how they function. The experimental logic pedagogy was implemented in-person (in three consecutive sessions) in an undergraduate computer science course, "COSC 243: Computer Architecture," during the Spring 2022 semester. A lecture on the fundamentals of logic gates was given to the students, as well as an overview of the experiment, including the materials used in the experiment and a detailed explanation of the experimental procedures. The students were given the experimental materials prior to the experiment. The list of experimental materials distributed to the students is shown in Table 1. The experimental teaching materials, which included laboratory instructions, images, videos, and other experimental guidance, were available online in Canvas. Everyone in the class was invited to take part in the experiment, which was done in person. Prior to the experiment, students completed a pre-lab assessment to assess their knowledge of the material, which was followed by a metacognitive survey. In addition, students were given a structured report guide to write about how they conducted the experiment, the ECP materials used, their observations, and the results. Using the "Classroom Observation Protocol for Undergraduate Courses" (COPUC), students' activities were observed in the classroom.

All digital circuits can be designed using three basic logic functions: **NOT** (invert), **AND**, and **OR**. Another useful logic function is **exclusive-OR** or **XOR**. Digital circuits operate on discrete signals. Digital signals vary in discrete levels and are usually in binary levels. Discrete levels in a binary signal are just two values: ON (True or 1) and OFF (False or 0).

Binary signals have two discrete logic levels or values:

- Logic 1: In this lab, a high voltage (5 V) is used.

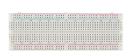
● Logic 0: a negative value (0V or ground)

Transistors, logic gates, and integrated circuits (ICs), also known as microelectronic circuits, microchips, or chips, are essential components in digital circuits. Each integrated circuit (IC) is a collection of electronic components such as transistors and diodes, capacitors and resistors, and their interconnections that are manufactured as a single unit on a thin semiconductor substrate (typically silicon).

Students used integrated circuits (ICs) as a combination of logic gates in this lab. These integrated circuits can be used to implement simple digital circuits like counters and decoders as well as more complex digital systems like microprocessors and microcontrollers.

- *The IC should be supplied with a power supply ranging from 4.5 V DC to 5.25 V DC.*
- *If the voltage of the signal is greater than 2 volts, the IC can identify it as a high-level signal.*
- *If the voltage of the signal is less than 0.8V, the IC can identify it as a low-level signal.*
- *The IC should be operated at temperatures below 70 °C.*

Table 1: Experimental materials distributed to the students

1	Breadboard			1
2	ADALM1000			1
4	LED, Green, Red			3
5	TTL IC, Quad 2-Input NAND Gate		7400	1
6	TTL IC, Quad 2-Input NOR Gate		7402	1
7	TTL IC, Hex Inverter		7404	1

8	TTL IC, Quad 2-Input AND Gate		7408	1
9	TTL IC, Quad 2-Input OR Gate		7432	1
10	TTL IC, Quad 2-Input Exclusive-OR Gate		7486	1

The ADALM1000 (ADALM1K) Active Learning Module is a simple tool for teaching the fundamentals of electrical engineering in an instructor-led or self-directed setting. This is the electronic device that connects the circuit board. It connects the relationship between voltage, current, and impedance to provide analysis capabilities for the circuits modeled in the experiment (resistance, inductance, and capacitance).

Figure 1: ADALM 1000 (M1K)

Experimental Procedures

First, the students were introduced to various types of breadboards, logic gates, jumper wires, and how to make proper breadboard connections. For this lab, students examine all possible input values (0 or 1) for all experiments and complete the truth table (Table 2) below for the AND, NAND, OR, NOR, and NOT functions.

X= 0 THE OUTPUT = 1 FOR NOT
X=1 THE OUTPUT = 0 FOR NOT

Table 2: Truth table to complete as lab experiment

X	Y	$X * Y$	$\overline{X * Y}$	$X + Y$	$\overline{X + Y}$
0	0				
0	1				
1	0				
1	1				

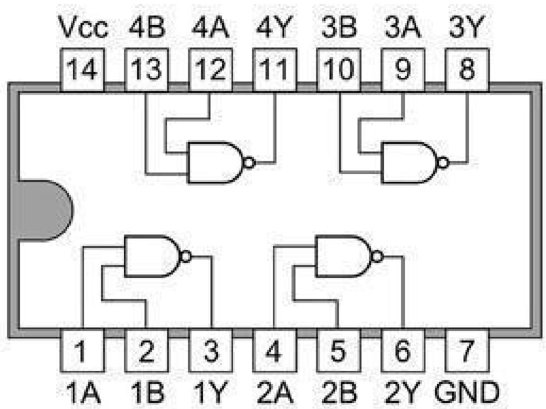


Figure 2(a) Example connections of the circuit for the NAND Gate

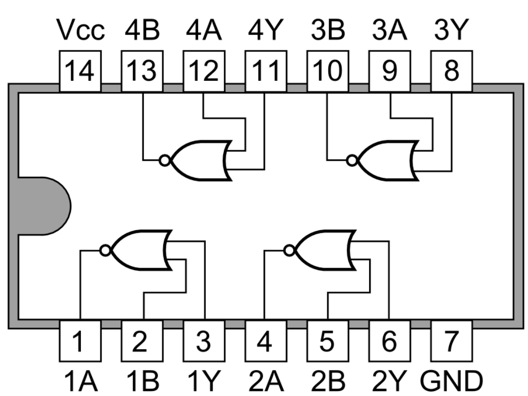


Figure 2(b) Example connections of the circuit for the Quad 2-Input NOR Gate

Based on Figs. 2(a) and 2(b) above, students built the circuits in Table 2 with various ICs by connecting pin No. 14 to the ADALM1000's 5V output and pin No. 7 to ground.

Each student was assigned a logic gate, a breadboard, an M1K, eight jumper wires, and two LED bulbs. The first experiment with a NAND gate was carried out, and the results were displayed to the student. In the following class, each student performed their individual experiments in groups of 5 under the supervision of the instructor in order to complete their lab exercise.

One of the difficulties the students encountered was understanding the logic gate naming system, which varies from manufacturer to manufacturer. Students were given a detailed explanation of how to identify logic gates using the last three digits at the start of the second session, while the initial names may differ from one manufacturer to the next. Students in this course were already familiar with digital logic and truth table concepts, but they were unfamiliar with circuit construction and electrical components. The circuit for this experiment was constructed with the assistance of the class instructor. The students were able to build their own circuits by the end of the second lab session.

Figure 3: Students setting up the experiment

They were also able to set up their experiment (Fig. 3) and collect data for analysis. Students collected data from the experiment as a group, with each student working on their logic gate while others observed and recorded the output.

The circuit construction and data collection took about 60 minutes to complete. The students were taught how to power the breadboard with the M1K and to connect the positive side of the board to the M15vK's and the negative side to ground. In addition, students were shown how to use jumper wires to connect the two sides of the breadboard by connecting the +ve to +ve and the -ve to -ve. Second, the students were taught the input and output pins on the two sides of each logic gate, with pin 14 for +VCC, which must be connected to the part of the breadboard designated as the power supply, and pin 7 for ground, which must be connected to the other part of the logic gate designated as the ground. Students were also taught that the remaining 12 pins, numbered 1 to 6 and 8 to 11, are input and output pins for different logic gates. The students used wires to connect the input and output on the breadboard to derive the output, and the led bulb was used as an indicator to determine the ON and OFF states of the logic gate experiment. When the lightbulb is turned on, it is one; when it is turned off, it is zero. The students were instructed to repeat the experiment using different logic gates to obtain the desired output.

Results and analysis

To evaluate the impact of ECP on student performance in the Computer Architecture class, we conducted three different evaluation metrics, each of which is discussed below.

1. **Signature Assignment Experiment**

At the beginning of the experiment, a pre-signature assignment was given to test the students' initial understanding of the experiment and background knowledge before conducting the experiment. In the end, students were given the same questions as a post-signature assignment to test their understanding after completing the experiment.

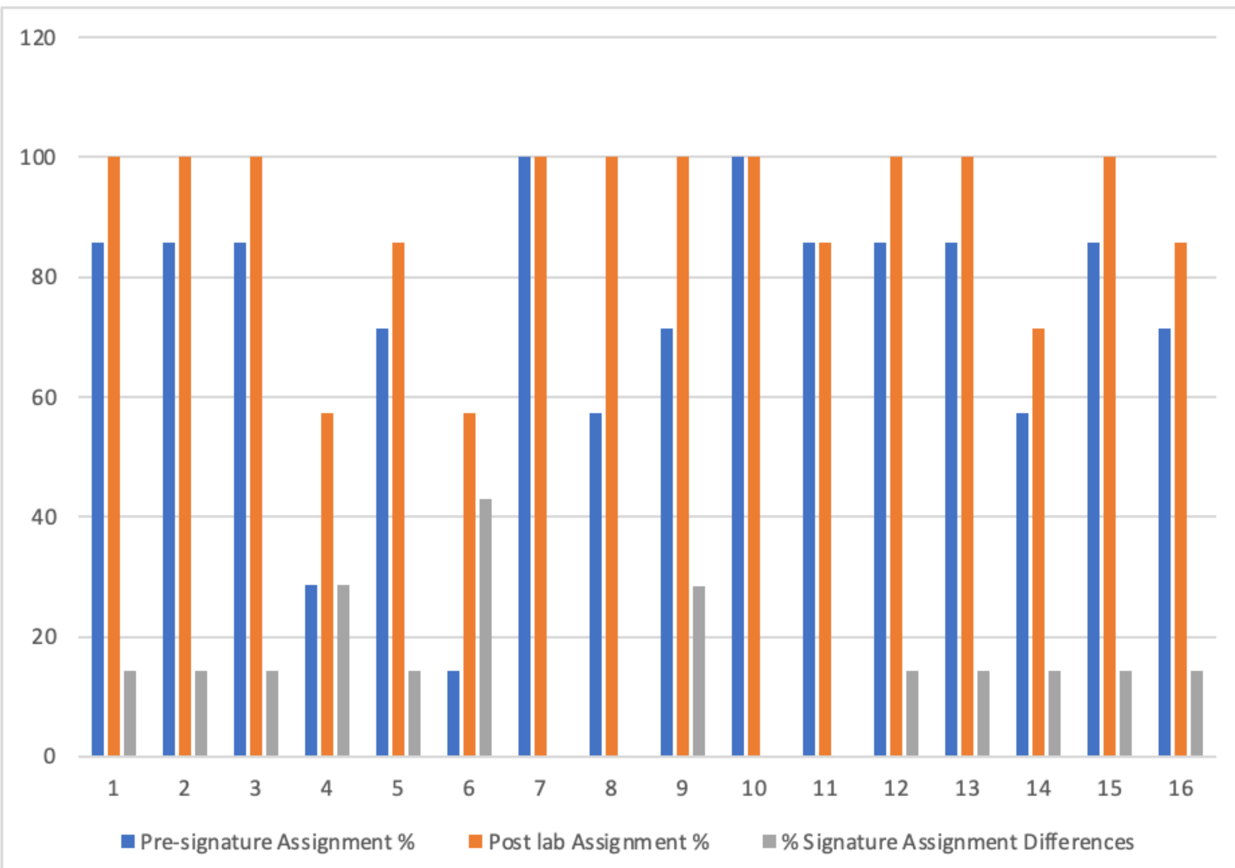


Figure 4: Students score percentage differences in the pre and post signature assignments

From the above chart, we can see that the performance of almost all the students improved after conducting the experiment, leaving only one whose performance did not decrease nor improve. This analysis shows that the students were able to retain and understand better the fundamentals of digital logic after the experiment.

2. **Student Engagement**

During the experiment's implementation, a survey called COPUS, which stands for Classroom Observation Protocol for Undergraduate STEM, was conducted to assess students' and instructors' engagement rates and activities during class, which were measured at 2-minute intervals for more than 50 minutes.

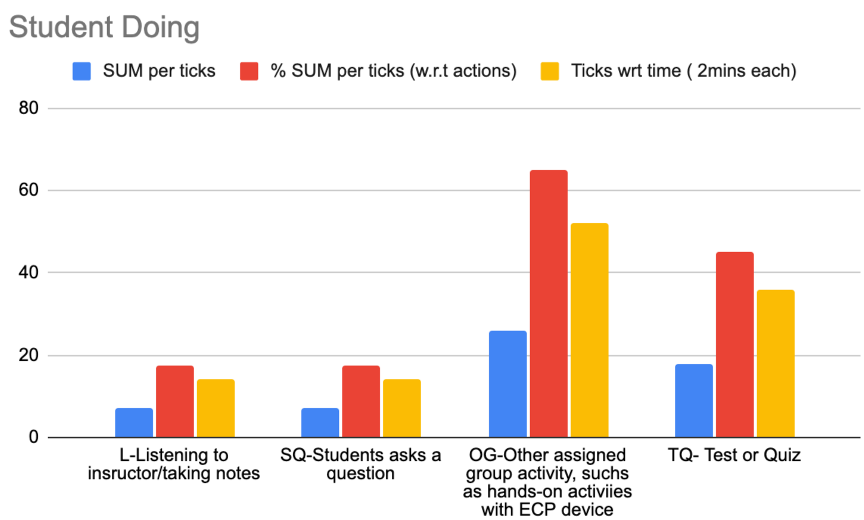


Figure 5: Students activities during the class experiment

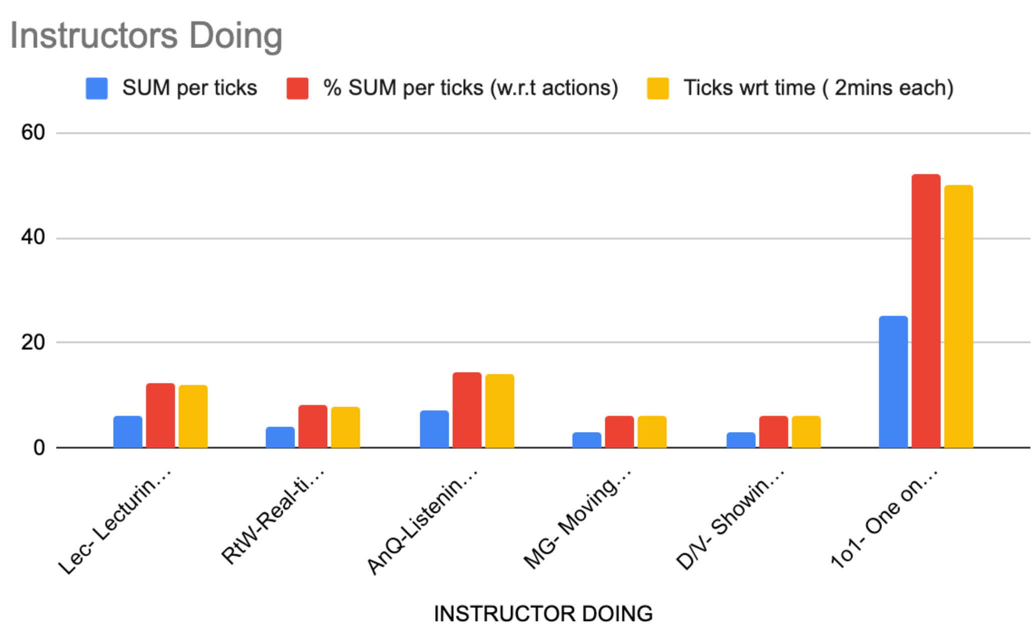


Figure 6: Instructor's activities during the lab session

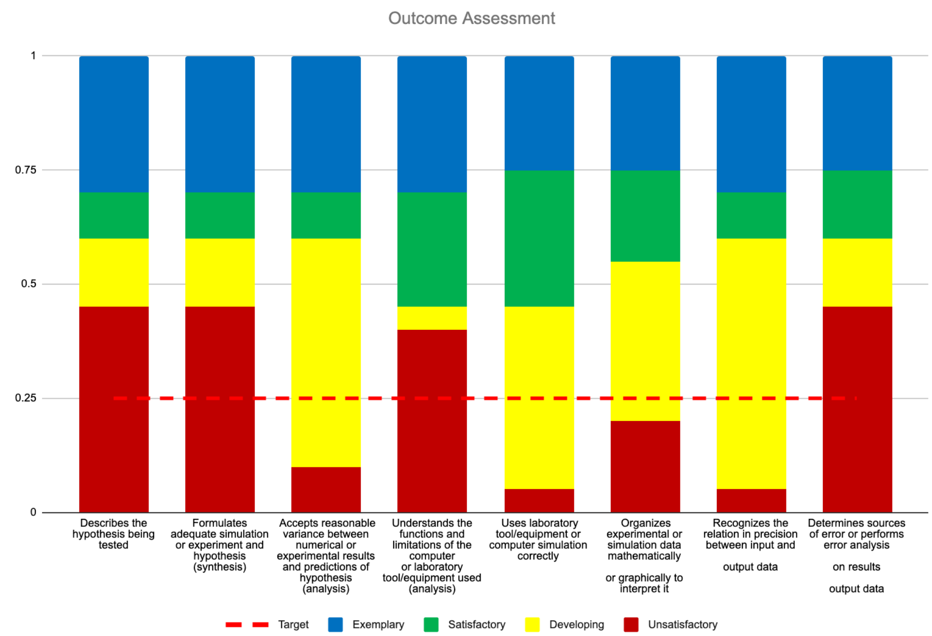


Figure 7: Students' Class Assessment Outcome.

According to the bar chart in Fig. 5, approximately 65% of the students were working on the experiment, with approximately 45.0% aiming to get the desired quiz result. This can also be seen as the instructor moves around the classroom having one-on-one discussions with the students (Fig. 6). The students' participation demonstrates their enthusiasm for the principles underlying logic gate operations. In addition, the results of the class experiments were analyzed in Fig. 7, which shows the percentage of students that performed below and above 25%. The percentage scale for each of the criteria was calculated based on the following formula:

*Performance criterion = (Total number of scores in each scale / Total numbers of scores) * 100*

3. **Post and Pre-Survey MSLQ**

Students also took part in a pre- and post-survey known as the Motivated Strategies for Learning Questionnaire (MSLQ). It is one of the most widely used survey instruments for assessing college students' learning strategies and academic motivation [16]. The data from this survey was analyzed to determine the effect of the experimental-centric pedagogy on the CS students who participated in the experiment, and the statistical differences between the post- and pre-survey were calculated using the t-test.

Discussion

The ten primary MSLQ constructs and codes used in the analysis are shown in Table 3. These constructs were all examined in the pretest and post-test surveys, and the student was given online forms to complete. Each student's response was graded on a 7-point Likert scale, with 1 representing "not at all true of me," 2, 3, 4, 5, 6, and 7 representing "true of me."

Table 3: Comparison of students in the pretest and posttest on the ten MLSQ constructs

Pre and Post MLSQ Constructs	Mean difference	SD	t	p
Intrinsic goal orientation	-0.037	0.873	-3.635	0.902
Extrinsic goal orientation	0.074	1.801	-6.102	0.905
Task Value	-0.037	1.670	-1.769	0.945
Expectancy Component	0.074	2.032	-4.481	0.912
Test Anxiety	0.333	2.015	-1.243	0.633
Critical Thinking	-0.148	2.007	-0.566	0.830
Metacognition	-0.194	1.629	-2.028	0.729
Peer Learning	0.333	2.363	-0.376	0.683
Interest Epistemic Curiosity Scale	-0.177	1.235	-3.818	0.677
Deprivation Epistemic Curiosity Scale	-0.155	0.999	-1.969	0.653

Note. n = 9 pretest students; n = 9 posttest students.

A paired sample t-test is used to determine the statistical significance of the pretest and posttest in those MLSQ constructs. It is a statistical technique used to compare two population means in the case of two correlated samples.

The t-value (t) in Table 3 is a ratio of the difference between the means of the two sample sets and the variation within the sample sets.

Degrees of Freedom (df) is simply the number of valid observations minus one, and Sig (2-tailed) is the probability (with a 95% CI) of observing a greater absolute value of t under the null hypothesis of no appreciable significance between the two sample tests.

Table 3 shows that posttest students differed from pretest students in terms of intrinsic goal orientation ($t(8) = -3.635$, $p = .05$), extrinsic goal orientation ($t(8) = -6.1$, $p = .05$), expectancy component ($t(8) = -4.481$, $p = .05$), and interest in epistemic curiosity ($t(8) = -3.818$, $p = .05$). A comparison of the four group means revealed that the difference between intrinsic goal orientation (2.18), extrinsic goal orientation (3.66), expectancy component (1.77), and interest epistemic curiosity (1.4) for posttest students was significantly higher on a scale of 1 to 7, with 1 representing very true of me and 7 representing not all true of me. Pretest students did not differ significantly from posttest students in task value (p =.115), test anxiety (p = 0.249), critical thinking (p =.587), peer learning (p =.717), or deprivation epistemic curiosity (p =.084). However, the group means comparison revealed that posttest students scored higher average points on these MLSQ constructs than pretest students. Taking into account all ten constructs, we are unable to disprove the null hypothesis that there is no discernible difference between the two sample tests.

Conclusion

This paper presents preliminary findings from the implementation of an evidence-based, experiment-focused teaching approach in a computer architecture course with the goal of increasing CS students' motivation and academic achievement. ECP employs a low-cost, safe, and portable electronic instrumentation system that is suitable for use in classrooms and student laboratories. The results of the internal course evaluation based on pre- and post-surveys showed that the introduction of ECP was successful while integrating it into the course, COSC 243: Computer Architecture, in Spring 2022. When ECP is implemented, the Classroom Observation Protocol for Undergraduate STEM (COPUS) results show more active student engagement. Integrating hands-on learning is one of the key approaches that has been shown to be effective in improving retention by making the learning experience engaging and motivating for students. This work aims to contribute to the development of a diverse, globally competitive STEM workforce by increasing literacy in hands-on learning in introductory digital logic and computer architecture/organization-related courses.

Appendix

Table 4: Shows the pretest and posttest MSLQ survey constructs.

MSLQ Items	**MSLQ Constructs**	**Code**
In a class like this, I prefer course material that really challenges me so I can learn new things	Intrinsic Goal Orientation	IGO 1
In a class like this, I prefer course material that arouses my curiosity, even if it is difficult to learn	Intrinsic Goal Orientation	IGO 2
The most satisfying thing for me in this course is trying to understand the content as thoroughly as possible	Intrinsic Goal Orientation	IGO 3
I am very interested in the content area of this course	Task Value	TV1
I like the subject matter of this course	Task Value	TV2
It is important for me to learn the course material in this class	Task Value	TV3

I believe I will receive an excellent grade in this class	Expectancy Component	EC1
I expect to do well in this class	Expectancy Component	EC2
I'm confident I can do an excellent job on the assignments and tests in this course	Expectancy Component	EC3
I have an uneasy, upset feeling when I take an exam	Test Anxiety	TA1
I feel my heart beating fast when I take an exam	Test Anxiety	TA2
I often find myself questioning things I hear or read in this course to decide if I find them convincing.	Critical Thinking	CT1
Whenever I read or hear an assertion or conclusion in this class, I think about possible alternatives.	Critical Thinking	CT2
I try to play around with ideas of my own related to what I am learning in this course.	Critical Thinking	CT3
If course materials are difficult to understand, I change the way I read the material.	Metacognition	MC1
Before I study new course material thoroughly, I often skim it to see how it is organized	Metacognition	MC2
Before I study new course material thoroughly, I often skim it to see how it is organized.	Metacognition	MC3
I try to think through a topic and decide what I am supposed to learn from it rather than just reading it over when studying.	Metacognition	MC4
When studying for this course, I often try to explain the material to a classmate or a friend	Peer Learning	PL2
I try to work with other students from this class to complete the course assignments.	Peer Learning	PL2
When studying for this course, I often set aside time to discuss the course materials with a group of students from the class.	Peer Learning	PL3

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