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Enhancing Student Engagement in Electrical Engineering: The Impact of Hands-On Learning Tools on Student Engagement

Dr. Shobhit Aggarwal, The Citadel

Dr. Aggarwal earned his Bachelor of Technology in Electronics and Communication from Kurukshetra University, India in 2014, a Masters of Science and Ph.D. in Electrical Engineering from the University of North Carolina at Charlotte in 2018 and 2023 respectively. After graduation, he served as an Embedded Firmware Engineer in an IoT-based Engineering organization in Charlotte and held a position as a Senior Embedded Software Engineer at a Fortune 500 electrical sector corporation in Raleigh. In Fall of 2024, Dr. Aggarwal joined the faculty of the Department of Electrical & Computer Engineering at The Citadel. There, he is the primary instructor for Computer Architecture, Embedded Systems, Data Communication and Networking, and Electrical Lab. His research interests span a wide range of topics, including IoT, Wireless Communication, Embedded Systems, Machine Learning, and Artificial Intelligence.

Dr. Gregory J. Mazzaro, The Citadel

Dr. Mazzaro earned a Bachelor of Science in Electrical Engineering from Boston University in 2004, a Master of Science from the State University of New York at Binghamton in 2006, and a Ph.D. from North Carolina State University in 2009. From 2009 to 2013, he worked as an Electronics Engineer for the United States Army Research Laboratory in Adelphi, Maryland. For his technical research, Dr. Mazzaro studies the unintended behaviors of radio frequency electronics illuminated by electromagnetic waves and he develops radars for the remote detection and characterization of those electronics. In the Fall of 2013, Dr. Mazzaro joined the faculty of the Department of Electrical & Computer Engineering at The Citadel. There, he is the primary instructor for Electromagnetic Fields, Interference Control in Electronics, Antennas & Propagation, and Electrical Laboratory courses.

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Abstract

In the evolving landscape of engineering education, engaging students and maintaining their interest is a persistent challenge. Traditional lecture-based teaching methods often fail to capture the attention of students, particularly those with demanding schedules, such as ROTC cadets. This study explores innovative pedagogical approach of using hands-on evaluation kit to address this issue.

This work studies the impact of the Sparkfun Inventor's Kit, on student engagement and interest in electrical engineering courses. The kit is simple to use, comes with a starter kit and has multiple example codes pre-written which are freely available. The code itself is very easy to understand even for the students that do not have an electrical and computer engineering background. This research aims to determine if providing students with opportunities to physically interact with electrical components can foster a more stimulating and effective learning environment. The findings of this study will contribute to a better understanding of pedagogical strategies that can motivate students and improve their learning outcomes in the field of electrical and computer engineering.

The participants of this study are about 60 ROTC freshman engineering students from different majors. Results indicate that students show significantly higher interest and energy levels during sessions involving hands-on tools, compared to traditional lecture-based classes where they often appear bored and sleepy.

Introduction and motivation

Most undergraduate engineering programs follow a traditional structure centered around lectures and laboratory sessions. This format provides students with a theoretical foundation through lectures, where concepts and principles are explained by instructors. Laboratory sessions, on the other hand, offer hands-on experience, allowing students to apply their theoretical knowledge to practical problems and develop essential engineering skills [1][2]. However, the increasing prevalence of digital distractions and the rapid pace of modern life have significantly impacted students' attention spans. Engineering education, characterized by its rigorous curriculum and demanding workload, faces the challenge of engaging students in a world where instant gratification and constant stimulation are the norm. The inclusion of engineering students in programs such as ROTC or athletics further complicates this challenge.

Engineering students in such programs face a particularly demanding schedule, often involving early morning physical training, drills, leadership exercises, and parades. This rigorous routine can leave them physically and mentally fatigued, impacting their ability to fully engage with complex theoretical concepts presented during lectures. While some students may be better equipped to handle such a demanding workload, the general trend is that a tired brain struggles to process complex information, leading to decreased attention and comprehension. As a result, educators face the challenge of keeping such students engaged and alert in the classroom. While the importance of theoretical concepts in engineering education is undeniable, it is crucial to consider the unique challenges faced by students. This confluence of factors necessitates innovative pedagogical approaches to optimize learning outcomes and ensure student engagement in engineering education.

To address the challenges of engaging engineering students, particularly those in demanding programs like ROTC, the "Introduction to Engineering" course [3] incorporates the "SparkFun Inventor's Kit" (SIK). By integrating hands-on projects and experiments directly into the lecture, students can immediately apply theoretical knowledge to real-world applications. This active learning approach not only breaks the monotony of traditional lectures but also caters to the diverse learning styles of students, including those with limited attention spans. The SIK's modular design and intuitive interface empower students to design, build, and test their own projects, further enhancing their problem-solving skills and appreciation for the engineering design process. This approach aligns with the need for innovative pedagogical methods that can capture students' attention and stimulate learning, even in the face of distractions and demanding schedules.

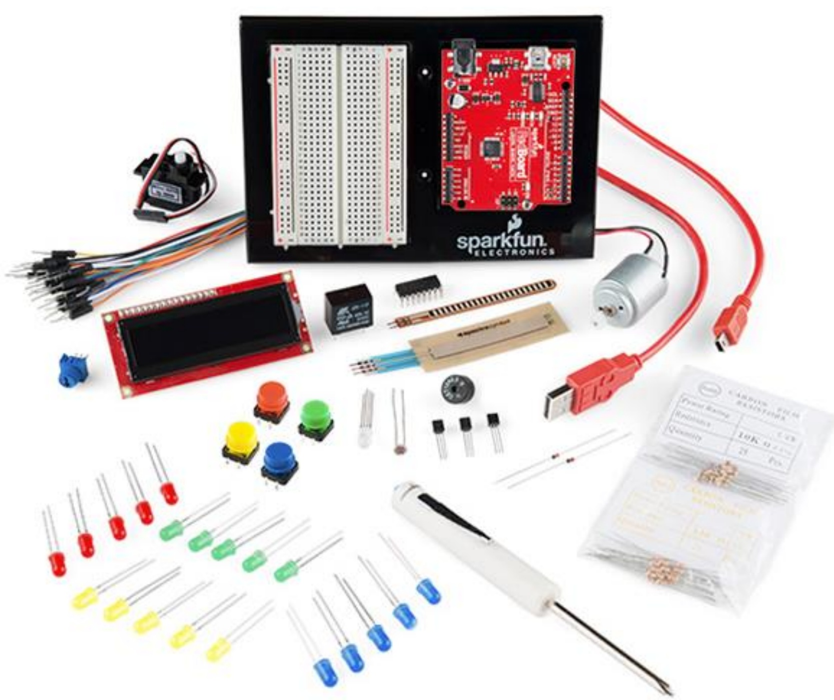


Fig. 1: SparkFun Inventor’s Kit: breadboard, microcontroller, and electronic components

This paper explores the significance of hands-on experimentation and project-based learning in cultivating a stimulating and effective engineering education specifically for electrical engineering in the age of short attention spans.

Introduction to engineering course structure

The Introduction to Engineering course serves as a foundational experience for freshman students, offering a broad exposure to the core principles of electrical, computer, mechanical, and civil and construction engineering. Approximately 180 engineering students (ROTC cadets) are divided into nine sections, each led by a faculty member from one of three departments.

To provide a comprehensive understanding of each engineering discipline, the course employs a rotational approach. Students spend three weeks immersed in a specific domain, delving into its fundamental concepts and exploring relevant engineering design processes. This structured approach ensures that students gain a solid foundation in each field, including relevant engineering design processes. By the end of the course, students have a comprehensive overview of the three engineering domains, empowering them to make informed choices about their major and future specialization.

The electrical engineering portion of the Introduction to Engineering course provides students with a solid foundation in fundamental electrical concepts. Students are introduced to key principles such as Ohm's Law, Kirchhoff's Laws, and the behavior of parallel and series circuits. Additionally, the course covers a range of essential electrical and electronic components, including resistors, capacitors, batteries, diodes, and servo motors, exploring their operation and applications.

To complement the technical content, the course integrates elements of engineering education and accreditation, emphasizing the importance of ethical practices and professional standards. Students are also exposed to engineering design concepts, learning to approach problem-solving systematically and creatively. The course culminates in training students in effective engineering solution presentation and data presentation and reporting, equipping them with essential communication skills for future academic and professional endeavors.

Employed teaching techniques

The Introduction to Engineering course employs a diverse pedagogical approach. This approach combines traditional lecture-based instruction with hands-on learning experiences.
Some classes follow a traditional format, where instructors deliver lectures to convey theoretical concepts and principles. However, to complement this approach, the course also incorporates hands-on projects, allowing students to apply their knowledge directly. These projects provide

opportunities for students to work independently or collaboratively, fostering problem-solving skills, critical thinking and teamwork. Additionally, some classes integrate theory and hands-on activities simultaneously. The goal of this blended learning approach is for the students to get much needed theoretical knowledge and reinforcing their understanding by applying that knowledge, connecting theoretical concepts to real-world applications.

For instance, the initial lectures focus on providing an overview of different engineering disciplines, courses offered within engineering programs, and the broader engineering landscape. Figures 2 illustrates two such lecture slides. In these lectures, students are provided with information in a traditional format however their perception of the topics are inquired.

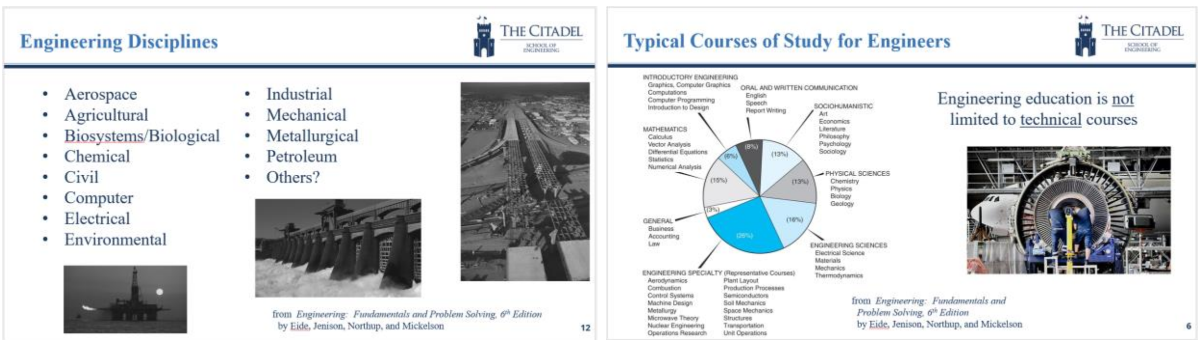


Fig. 2: Lecture slides illustrating various engineering disciplines and courses in engineering program

Subsequently, the course transitions to a mix of theoretical instruction and hands-on activities. Students are introduced to various electrical and electronic components, engineering design processes, and other relevant topics. The SIK is employed to facilitate hands-on activities, enabling students to experiment with circuits and programming. Figures 3 and 4 illustrate slides with theoretical concepts and hands-on activity respectively for electrical engineering concepts. Figures 5 illustrate slides with theoretical concepts and hands-on activity for the engineering design concepts.

To ensure accountability and promote active learning, students are required to submit observations and notes online. These submissions are graded, and they also contribute to class attendance. By integrating hands-on activities with theoretical instruction, the course creates a more engaging and effective learning environment. Students are motivated to pay closer attention to lectures, as they understand that the knowledge gained will be applied in practical exercises. Moreover, hands-on activities provide immediate feedback to both students and instructors. Students can identify areas where they need further clarification, while instructors can gauge the overall understanding of the class and adjust their teaching approach accordingly.

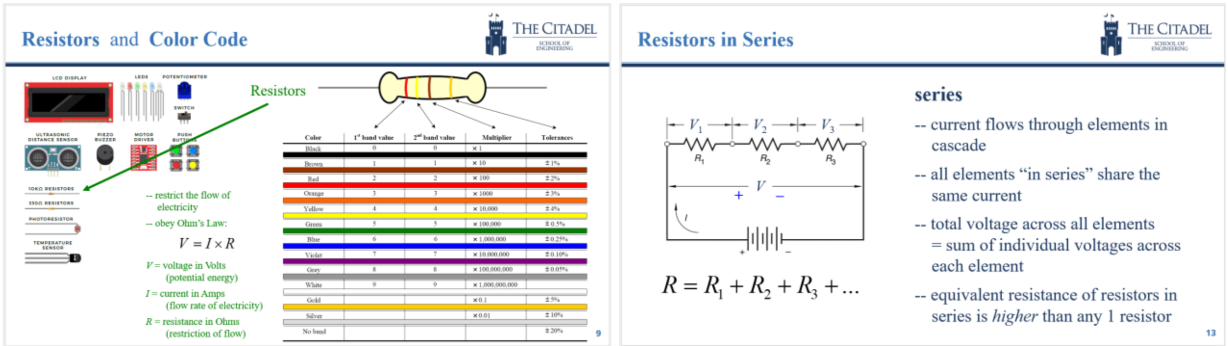


Fig. 3: Lecture slides illustrating theoretical concepts of electrical engineering

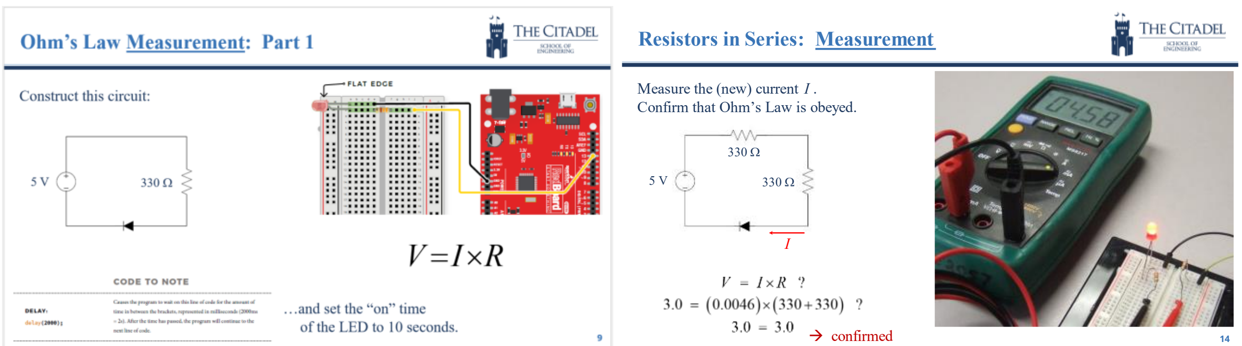


Fig. 4: Lecture slides illustrating hands-on activities for theoretical concepts

Fig. 5: Lecture slides illustrating theorical concept and hands-on activity for engineering design concept

The course also incorporates dedicated hands-on sessions, where students can fully immerse themselves in practical projects. The SIK provides a comprehensive manual with step-by-step instructions for building various projects. Figure 6 illustrates those projects.

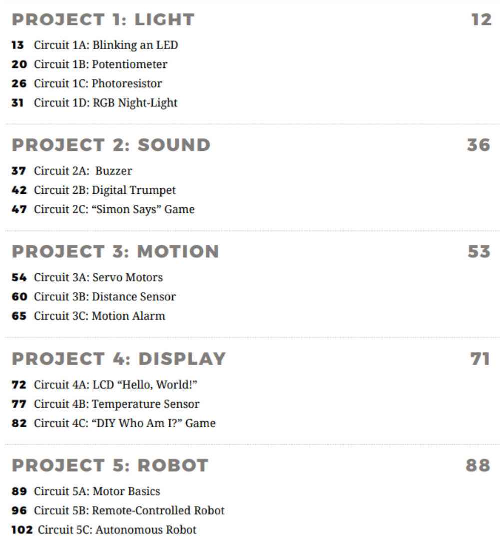
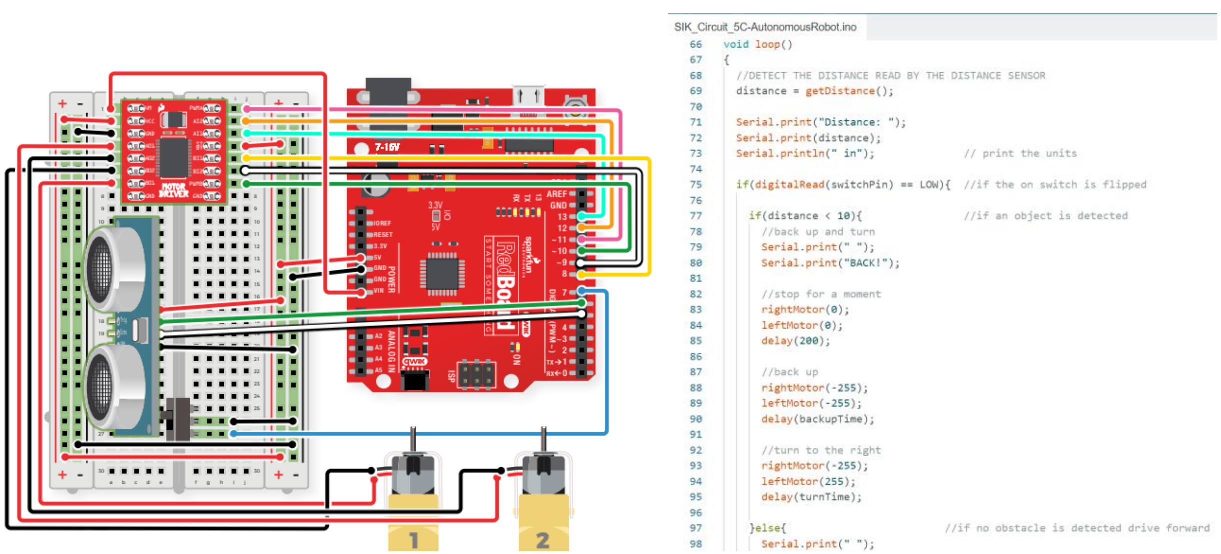


Fig. 6: Projects available in the Sparkfun inventors kit

Students are encouraged to choose projects that align with their interests. They have to realise the circuit first then program the Arduino board to take inputs and control the circuit. Figure 7 illustrates the circuit diagram and Arduino IDE code snippet for one of the project (autonomous robot). While the SIK provides example code for these projects, students are challenged to modify and extend the code to achieve specific outcomes. This task necessitates a deep understanding of the code's structure and functionality, fostering critical thinking and problem-solving skills. By actively engaging with the code and experimenting with different modifications, students gain valuable experience in programming and engineering design.




```
void loop()
{
  //DETECT THE DISTANCE READ BY THE DISTANCE SENSOR
  distance = getDistance();

  Serial.print("Distance: ");
  Serial.print(distance);
  Serial.println(" in");              // print the units

  if(digitalRead(switchPin) == LOW){  //if the on switch is flipped

    if(distance < 10){                //if an object is detected
      //back up and turn
      Serial.print(" ");
      Serial.print("BACK!");

      //stop for a moment
      rightMotor(0);
      leftMotor(0);
      delay(200);

      //back up
      rightMotor(-255);
      leftMotor(-255);
      delay(backupTime);

      //turn to the right
      rightMotor(-255);
      leftMotor(255);
      delay(turnTime);

    }else{                           //if no obstacle is detected drive forward
      Serial.print(" ");
```

Fig. 7: Circuit diagram and code snippet for the autonomous robot project

Fig. 8: A group of 2 students successfully implementing the autonomous robot

To further enhance practical skills and foster a sense of ownership, students are introduced to soldering techniques. They receive safety training and practice soldering basic components like resistors, capacitors, and LEDs on dedicated practice boards. Once proficient in soldering, students are provided with a kit containing all the necessary components to assemble a handheld gaming device. This kit includes a base PCB board, an LED-based grid screen, resistors, capacitors, push buttons, a USB port, a battery pack, and other essential components. By assembling and soldering these components, students gain hands-on experience in electronics assembly and circuit construction. The completed gaming device can be taken home by the students, reinforcing their sense of accomplishment and ownership of their learning.

Fig. 9: Students assembling and soldering the gaming device

Survey results and discussion

A survey from the students was taken to quantify the effectiveness of traditional teaching techniques and hands-on learning. The survey was taken at the end of each rotation, so the students have a clear understanding of different learning techniques employed in the course. A total of 67 students took the survey. The results of the survey are illustrated in the subsequent figures.

Figure 10 represents the majors of the students who took part in the survey. The majority of these students are in mechanical engineering, then civil and construction engineering, and then electrical engineering. These numbers are also in synchronization with the number of students enrolled in the school of engineering.

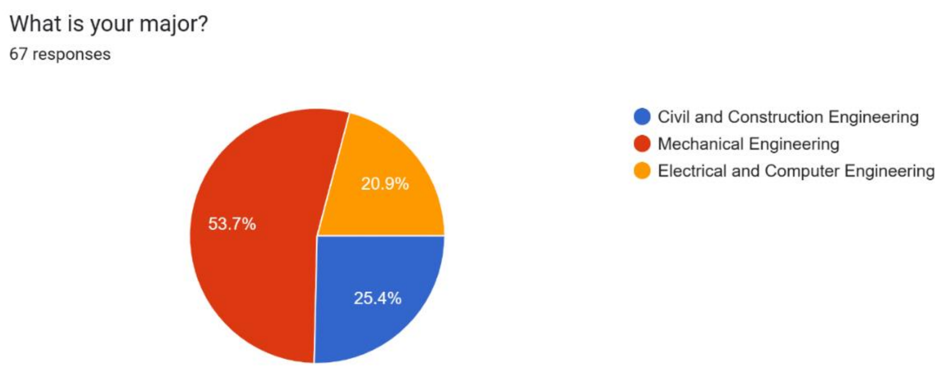


Fig. 10: Distribution of students in different engineering majors

The students were asked about their preferred style of learning and the reason behind that. Figure 11 illustrates that a wide majority of students have hands-on learning style as their preferred way of learning. The remaining students prefer a mix of both the traditional and hands-on approach. Figure 12 illustrates that most of the students find the preferred approach more engaging and interesting. They also responded by saying they learn by doing as it helps them to visualize the concepts. The low percentage of responses indicating awareness of potential inattentiveness among ROTC cadets may suggest a reluctance to acknowledge that they could experience lapses in focus during lectures. Some students even tend to stand during the traditional lecture delivery, just to stay awake. Such a behavior is never observed during the hand-on activities. When asked about the benefits of their preferred learning style the responses conclude that their preferred style motivates them and helps with the retention of the information. When the students work on hands-on activities the human brain can connect the theoretical information with hands-on experience and hence the information gets embedded in their memory for a longer period of time. The experience of solving critical problems at hand as presented by the activities forces them to think logically and improves their understanding of the concepts.

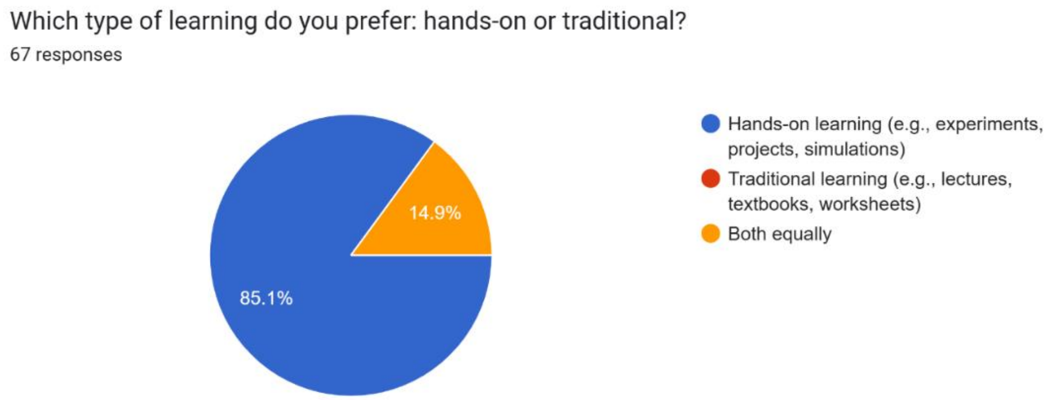
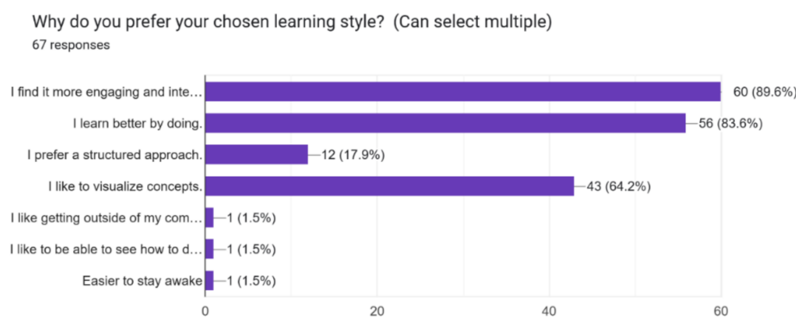
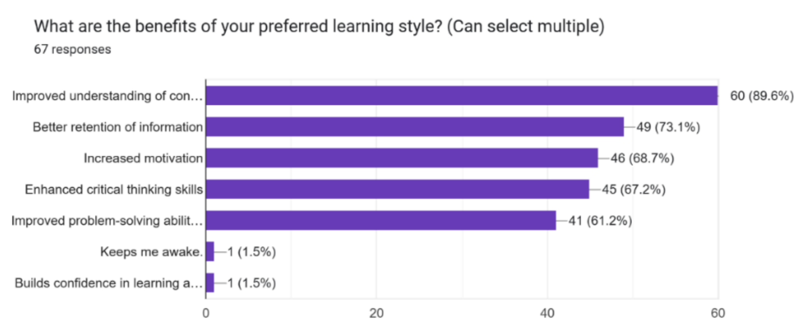


Fig. 11: Students' preferred way of learning



(a)



(b)

Fig. 12 (a) Reasoning for the preferred learning style (b) benefits of preferred learning style

They were also asked direct questions to compare hands-on learning with traditional learning (Figure 13). Most students find hands-on learning to be more engaging, effective and fun. Since ROTC cadets with challenging schedules feel these activities as fun and engaging, they enjoy the process of learning this way.

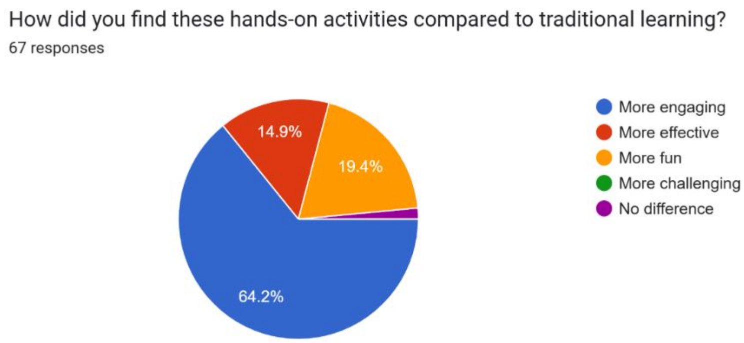
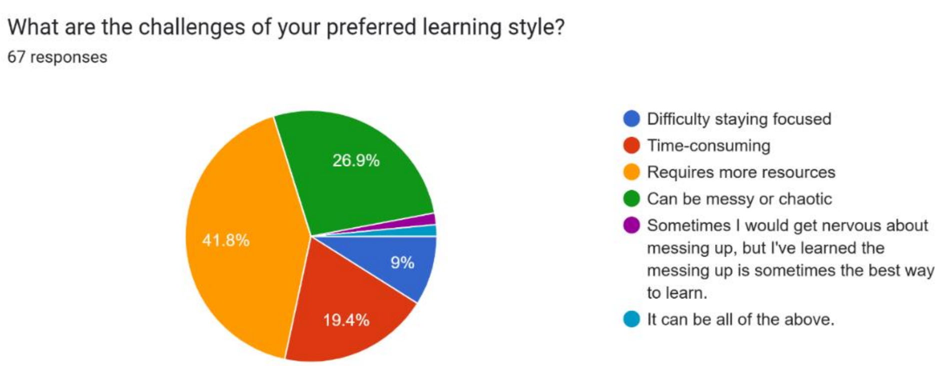
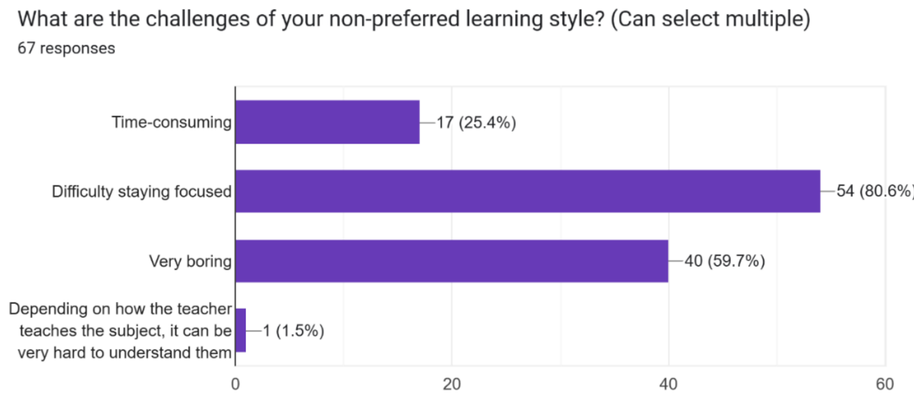


Fig. 13: Comparison of hands-on vs traditional learning styles

They also responded about the challenges for their preferred learning style (Figure 14), majorly the requirement of more resources in terms of time and cost. Sometime the students are not able to get the entire activity done in one class period and may have to come back to get it completed. It has its own merits and shortcomings. Students feel they must put in more time to get past a challenging activity. They must connect several wires on the SIK to get the project to work and if there is a single loose connection in the system it becomes very messy and chaotic to debug. However, it teaches them the importance of perseverance while improving their critical thinking and problem-solving skills. One of the students gave a remarkable response that "Sometimes I get nervous about messing up but I've learned the messing up is sometimes the best way to learn". The response shows the student's willingness to take the tough and more challenging route. As future engineering dealing with challenges to solve critical problems is an important skill that they are learning early-on in their journey. They were also asked about the challenges for the non-preferred learning style and majority of students responded by saying its boring and poses difficulty to stay focused.



(a)



(b)

Fig. 14 Challenges to (a) preferred learning style (b) non-preferred learning style

Despite the challenges faced by the different learning styles, students believe that hands-on learning helps them to understand the concepts better because they can apply those concepts in real-life. Since they are given tasks to modify the existing SIK projects, they feel much more comfortable modifying, experimenting, exploring and discovering more applications and use case of the concepts taught during the learning process (Figure 15).

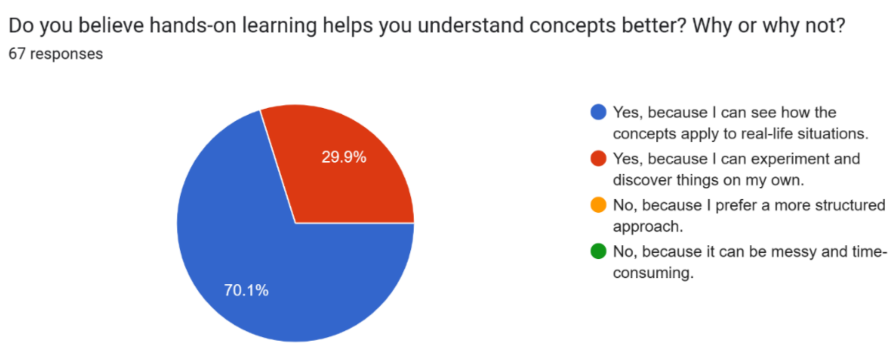


Fig. 15: Students prefer a hands-on approach

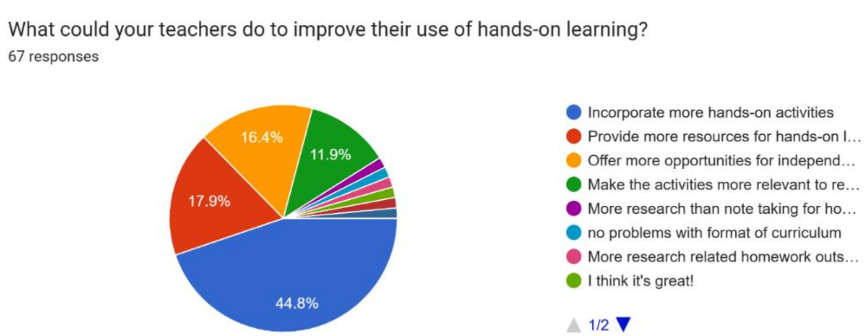


Fig. 16: Students want more hands-on learning

Conclusion

This study demonstrates the potential of hands-on learning tools, such as the Sparkfun Inventor's Kit, to significantly enhance student engagement and interest in electrical engineering. By integrating both traditional and hands-on approaches into the introductory engineering course, we were able to create a more dynamic and effective learning environment. Hands-on activities, including soldering, circuit building, and programming with the Sparkfun kit, enhance student engagement in class. Students actively participated in in-class discussions, presentations, and group projects, further solidifying their learning and keeping them engaged as well as awake.

The survey results confirm that students strongly prefer hands-on learning experiences, indicating a significant positive impact on their motivation and overall satisfaction with the course. These findings suggest that incorporating similar hands-on activities into other engineering courses, such as Computer Architecture, Digital Logic, and Data Networks, can lead to reduced classroom lethargy and improved learning outcomes. This experience has also shifted our perspective on student behavior. We can create a more stimulating and student-centered learning environment by providing opportunities for hands-on exploration and experimentation. Moving forward, we will continue to integrate hands-on activities into our courses to inspire future engineers and foster a passion for innovation.

References

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