WIP - Integration of Voice Technology into First-Year Engineering Curriculum

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Nicole Bosca

Work-in-Progress – Integration of Voice Technology into First-Year Engineering Curriculum

Introduction

This is a work-in-progress paper. Voice technology is a growing field and is becoming more prominent in our day-to-day lives. National Public Research, in a study conducted in early 2020, found that an estimated 60 million people (24% of total U.S. adult population) own a voice-enabled smart speaker [1]. The number of smart speakers in the U.S. household has grown by an astounding 135% in last two years [1]. Voice incorporated devices serve people of different age groups, disabilities and even professions. The latest versions can also function within limits based on the preferences, choices and past behavior of its users [2]. Smart speakers and voice assistants are increasingly becoming a part of our daily lives.

The Amazon Alexa devices are one such cloud-based, continuously improving, digital assistants designed to respond to voice commands. One of the newer innovative applications of the Amazon Alexa devices is its integration into higher education. However, most of this integration has been through campus life and residence halls or higher-level programming courses [3] [4].

This paper summarizes our efforts on embedding voice technology into a first-year engineering design (FED101) course in the Newark College of Engineering (NCE) at New Jersey Institute of Technology (NJIT) that reviews the basic concepts of engineering and introduces some tools used for the design and implementation of devices and systems. The goal is to enhance student learning through hands-on projects in first-year design courses and use this to not only further engage students with the course content, but also foster the skills necessary for effective communication on projects with multiple stakeholders. Students, with very little background on the subject, are able to design a working device such as a portable fan, a remotely controlled car, or a robotic arm. Students are using Computer-Aided Design (CAD) software, making the parts with 3D printers, creating an Arduino code to control the action of their device, and finally writing a voice interface (given a skeleton code) to actuate the servo motors on the device using voice commands. For example, students use voice to turn a fan on or off, change its speed, and enable oscillation.

Ours is a unique approach towards not only integrating new emerging technology into the classroom but also finding new ways to engage students and help them learn new skills. Upon completion of this pilot, students are expected to have expanded their technical knowledge as well as soft skills such as communication, collaboration, and listening skills. They will have learned how to personalize Voice technology, and the researchers would have improved the course design as well as prepared for the study to be offered on a larger scale.

Methodology and Implementation

The fundamentals of engineering design (FED101) course at NJIT is offered to all incoming engineering students. Students take different versions of this course depending on their major, although, the goals and learning outcomes are consistent across all offerings. The authors are involved in planning and instruction of this course for the General Engineering student population. General Engineering houses students that are still-deciding on their major and those who are underprepared for engineering study based on their application data. In Fall 2019 three sections of FED101 course were offered for General Engineering, with 80-90 students in total. This course is set up as a common lecture for all three sections and separate laboratory experiences in a computer lab. In each of the three sections, students are asked to form teams of three.

Each team comes up with an idea for a voice-technology enabled smart device for their final project. The final project has the students design and 3D print parts for their intended device and then assemble them before the voice-technology integration. Students then have to learn Arduino coding and update skeleton codes in order to control and operate the actions of their voice-technology enabled devices. Since FED101 is offered to students with no or minimal knowledge and background in 3D modeling and Arduino coding – the design problem is broken into four sequential milestones. Students have to report separately on each milestone. Detailed description on each of the four milestones is given below:

Milestone 1: Smart Device Design Identification and Hand-sketching

The focus of the final project is the integration of diverse engineering skills, learned during the course of the semester, into building a neat smart device, whose actions are controlled via voice commands. Therefore, the first objective of the project is to gather potential ideas. This task is crucial, not only for students to understand the design limitation and constraints, but also to learn and build teamwork skills. After protracted team-discussions, each group comes up with their design project taking into consideration many factors such as complexity, feasibility, and innovation. Although contemporary students are somewhat equipped with CAD skills that facilitates the whole design process, for the most part they lack hand-sketching skills. Thus, creating hand-sketches for their design project is an essential aspect of this milestone. Overall, this milestone helps students in building teamwork skills as well as starting to learn technical communication (reading and creating basic technical drawings).

Milestone 2: 3D Modeling and 3D Printing the Smart Device Parts

Over the course of the semester, students are taught basic-to-intermediate level 3D modeling skills. Students are asked to implement all they have learned into designing and 3D modeling their smart device. By the completion of this stage, students are expected:

(1) To translate their ideas from on-paper designs into models on a CAD software (Creo Parametric 6.0 in our case).

(2) To bring their 3D models to life by 3D printing their designs.

At the end of this stage, students have all the parts that constitute the smart device 3D printed and ready to be assembled.

Milestone 3: Building the smart device control circuit

In preparation for building the control unit for their smart device, students:

1. Are introduced to and taught about the functionality of various electrical components such as DC motor, servo motor, transistors, and LEDs.
2. Receive training on how to write basic Arduino code to control the speed of a DC motor and the position of a servo motor (students have to make slight modifications to skeleton Arduino codes that are provided to them).

Additionally, TinkerCad, a free online software, is used to virtually build and simulate circuits – as a step before building the project with real components. At this milestone, the focus is on coding the smart device actions using electric components (e.g. DC and servo motors) and using a micro-controller as a control unit (Arduino UNO is used for this purpose). The block diagram of this milestone (milestone 3) is shown in Figure 1. The inputs to this block diagram (in Figure 1) are control signals and the outputs are responses that cause the actions of the smart device. For example, the motor connected to PIN2 of the Arduino UNO will start rotating when PIN10 reads a HIGH voltage. In this example, the control signal is the HIGH input signal on PIN10 and the action is the motor rotation.

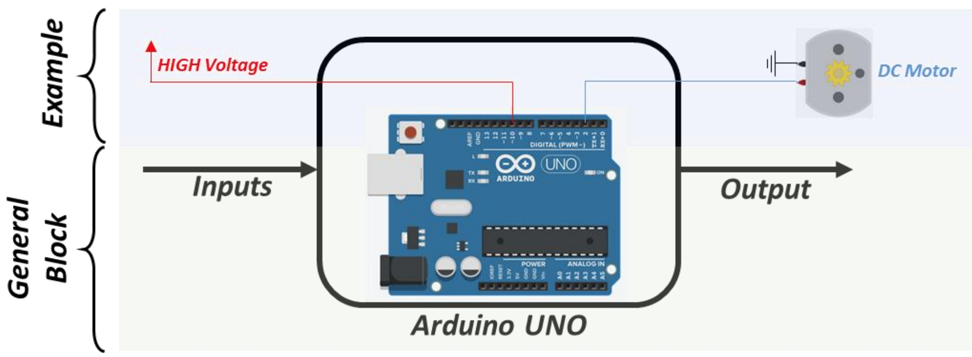


Figure 1. Block diagram of "Milestone 3." The Arduino UNO and DC motor are taken from TinkerCad.

Milestone 4: Integration of voice technology

A NodeMCU, a micro-controller that has a built-in ESP8266 WiFi chip, is used to send commands wirelessly from any smartphone (via Alexa application) to the Arduino UNO (main control unit). A cloud server is also used to transmit Alexa commands towards the NodeMCU. The students are provided with a skeleton code for the NodeMCU and are asked to make minor modifications to the code as needed for their project. In addition to the skeleton code, a project instruction manual is shared with the students that encloses directions on how to:

1. create a Sinric (cloud server) account,
2. download and install Alexa application on their smartphones,
3. connect to NodeMCU.

Figure 2 shows the workflow of information transmission from the smartphone to the NodeMCU. The workflow output can be used as an input to the Arduino UNO (see Figure 1).

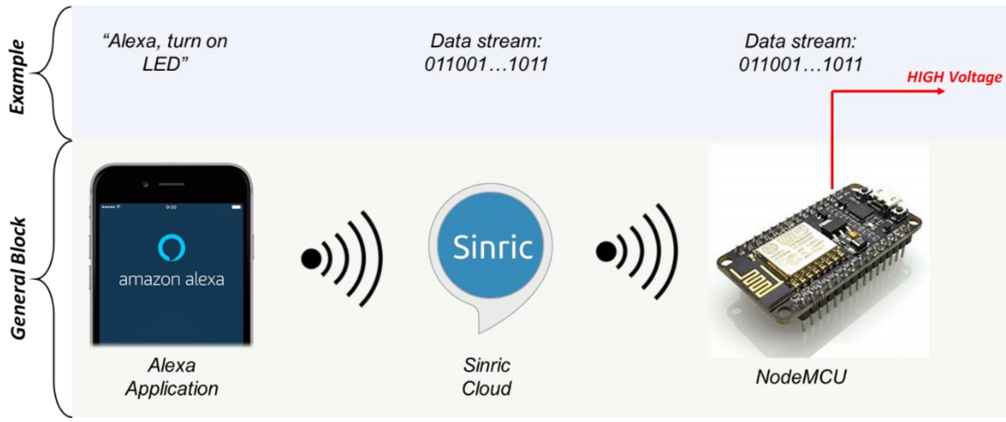


Figure 2. Workflow of information transmission from the smartphone to the NodeMCU.

Milestones 2, 3, and 4 help students develop technical skills (3D modelling and printing, Arduino coding, and circuit building). In whole, a two-step learning strategy is employed where firstly students are exposed to a skill by learning basic commands and tools using tutorials. In the second step, they hone these skills further by implementing them in building a product with a real-life application. At the end of the project, all teams are required to make an oral presentation of their work. This helps them to enhance their public-speaking skills.

Project Example

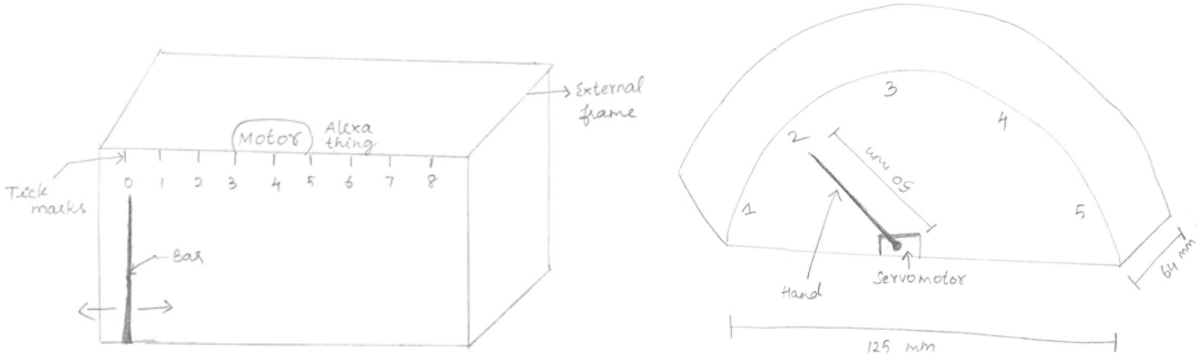
The "Smart Timer" is one of the design ideas implemented by the students. It is a timer that could be set to either 1 or 2 minutes and then start counting down until the preset time is up. Time was set with one of the two "Voice Commands" (commands corresponding to one and two minutes). For example, say "*Alexa, turn one minute ON*," and the timer will be set to 1 minute and then starts counting down.

Figures 3 (a) and (b) are two hand-sketches of the "Smart Timer". Figure 3 (a) is the first design hand-sketch which is a rectangular timer that has a sliding bar. The motor in this design comes on top and sweeps the bar left and right. After discussing the design features (rectangular block and sliding bar), students realized that a circular frame with a clock hand will make their design easier to implement. Figure 3 (b) shows the hand-sketched new design.

A servo motor was used to set the clock hand's position (1 or 2 minutes) and counted down when commanded with Alexa. Both positioning and counting down codes were uploaded to the Arduino UNO – the main control unit. Additionally, NodeMCU was used to wirelessly send commands from the smartphone to Arduino UNO. If one says: "*Alexa, turn one minute ON*," then the following series of action will take place:

- Alexa application will send a command to the NodeMCU,
- the NodeMCU will convey the command to Arduino UNO,
- the servo motor – connected to the output of Arduino UNO – will go to the 1-minute-position and then start counting down until the preset time is up.

Figure 4 shows the full project assembly.



(a) (b)

Figure 3. (a) Original timer with rectangular frame and sliding bar – (b) New timer design with circular frame and clock hand

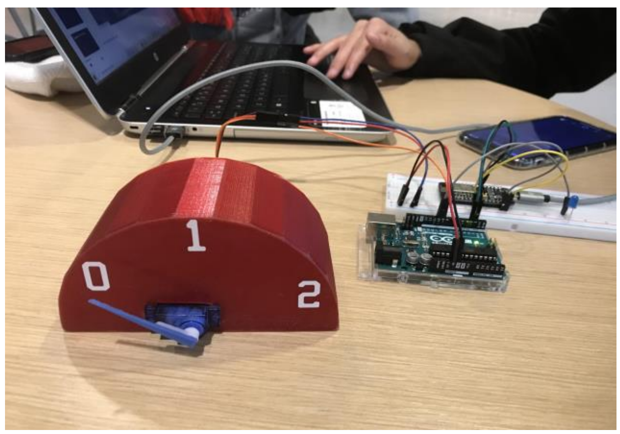


Figure 4. Full project assembly

Student Feedback and Discussion

In order to assess the effectiveness and impact of this new project concept on students, a survey was developed that students were asked to take upon completing the project. This survey was to assess if the project helped students in developing technical as well as soft skills that would help them succeed in their academic life at NJIT and in the real world too. The survey was anonymous and participation did not have any influence on student's grade in the course. However, students were highly encouraged to complete the survey. As this survey was administered at the end of the semester, a slightly low response rate (58%) was observed. The survey questions focused on two aspects; (1) Technical aspect and (2) soft-skills (e.g. communication, collaboration, and listening skills). These were the only questions asked as part of a post-survey.

For the technical aspect of the project, the interest was to see if the project had helped students improve their Arduino coding, 3D modeling, and voice technology skills. Therefore, students were asked to describe their experience by agreeing or disagreeing to the following statements for the three categories (Arduino coding, 3D modeling, and voice technology):

1- This project helped me improve/understand my coding/3D modeling/voice technology skills.
2- I will use the coding/3D modeling/voice technology skills I learned to build more projects in the future.
3- What I learned on coding/3D modeling/voice technology has met my expectations.

Figure 5 presents a summary of students' answers to the three abovementioned statements for three categories; 3D modeling (first category), Arduino coding (second category), and voice technology (third category). The bars were constructed based on responses from a sample of 52 students (response rate ~58%). It appears that the students have found the 3D modeling activity very helpful as more than 80% of the students agree (or strongly agree) that their 3D modeling skills have improved (Figure 5, left sub-plot, first category) and they will implement skills they learned in order to build more projects in the future (Figure 5, middle sub-plot, first category). Additionally, the 3D modeling skills they learned have met their expectations (Figure 5, right sub-plot, first category).

When it comes to Arduino coding and voice technology, the results were not as excepted. Less than 50% of the students (taken from the sample of 52 students) agreed (or strongly agreed) that this project (smart device project) has helped them improve their coding skills and voice technology understanding. Students were also provided an open-ended prompt to provide general comments on the project. A sample of five comments taken from five different students is provided in Table 1. These comments are a good representation of most, if not all comments received. It is concluded that the majority of the students have faced difficulties in Arduino and NodeMCU coding.

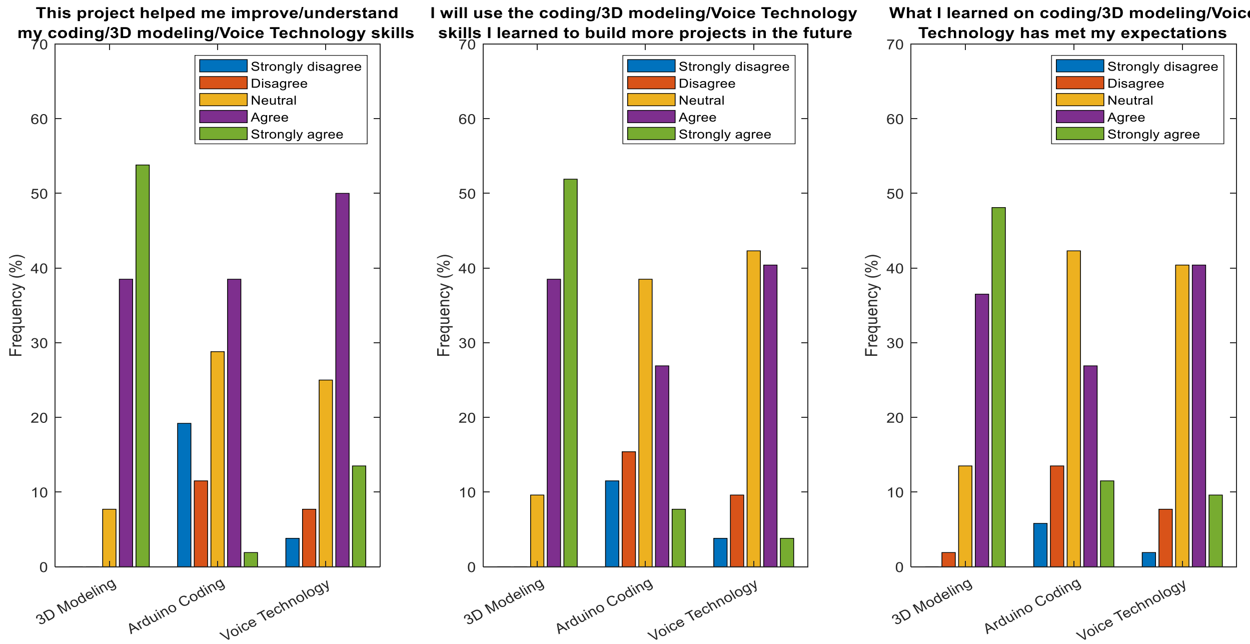


Figure 5. Students' response to the three abovementioned questions under three categories; 3D modeling, Arduino coding, and voice technology.

Furthermore, it was investigated how this project affected students' creativity and innovation, technical communication, and collaboration with teammates. Students were asked about the impact of this project and the above-mentioned skills (creativity and innovation, technical communication, and collaboration with teammates). Their answers are reported in Figure 6 that shows that this project has helped students develop teamwork skills (as more than 75% of the students agreed or strongly agreed), become more creative and innovative (as more than 80% of the students agreed or strongly agreed), and improved their technical communication (as more than 60% of the students agreed or strongly agreed). The bar graphs were constructed based on responses from the same sample of 52 students.

Table 1. Students' comments on Arduino coding and voice technology modules

Students	**Comment**
Student 1	Arduino coding was difficult for me, and coding is not really what I enjoy about the engineering process, but it was good exposure.
Student 2	Overall Arduino coding was pretty difficult and I wish that more information on how to code was provided.
Student 3	I wish there was more practice with the coding before using Arduino.
Student 4	Voice technology was also pretty difficult and the instructions on how to incorporate voice technology weren't easy either.
Student 5	If we spent more time learning how to code, this would have gone a lot smoother. I think the voice tech part was very interesting, but disappointed I couldn't get to know it more.

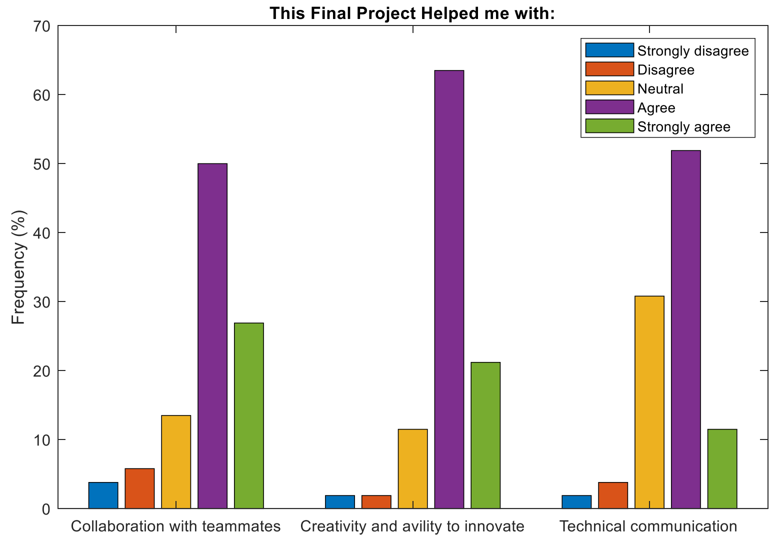


Figure 6. Students' response on how did the final project help in developing creativity and innovation, technical communication, and teamwork skills.

Summary, Limitation, and Future Work

Summary: When it was decided to implement this project, the expectation was that students would expand their communication, collaboration, and listening skills, in addition to being exposed to engineering design by learning how to build their own personalized smart device that could be controlled with voice commands. It was concluded that this project has helped the students develop and/or improve some of the technical (3D modeling), communication, collaboration and teamwork, and listening skills. However, since the coding concept was very new, students have found coding hard, and this has appeared in their feedback (Figure 5) and comments (Table 1) as well.

Limitation: At the current stage, the mechanism used for the assessment of the effectiveness and impact of this new project concept presented some limitations. The first limitation is the low response rate to the survey. Here we mention some factors that we believe have caused a low response rate:

- The survey was anonymous and was not counted towards students' grade.
- Lack of specific incentive for the person answering the survey (since it was on a voluntary basis and not a compulsion).
- Unwillingness to disclose personal opinion.
- Survey fatigue from responding to too many surveys conducted in general.

Another limitation is that the survey taken upon project completion was not linked one-to-one to a pre-survey. Also student self-assessment has a disadvantage that students might over-evaluate or under-evaluate their performance. As a result, it was difficult to quantify the rate of improvement and concept understanding.

Future Work: In order to solve the issues presented above and address the project limitations, it was decided to

(1) spend more time on teaching basic Arduino coding along with simple and straightforward projects that could be built on Arduino UNO (e.g. use switch to turn on and off LED),
(2) develop a pre- and a post-survey that ask the same questions, and
(3) make the surveys mandatory in order to obtain a higher response rate.
(4) consider mechanisms other than self-assessment.

The results of the improved course will be reported in a separate paper in the future.

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