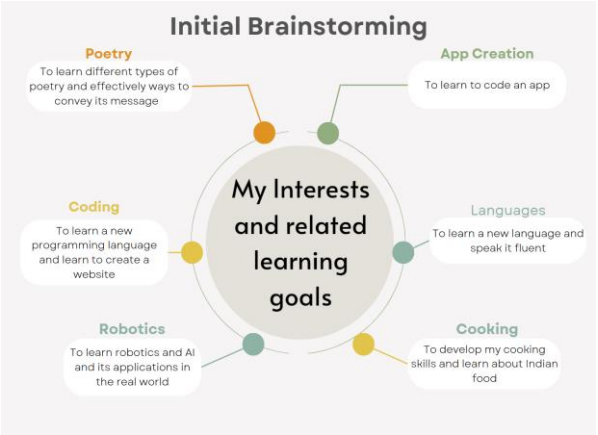
A Bluetooth-Controlled Autonomous Robot Car

Criterion A: Planning

Learning Goal

Robotics and Artificial Intelligence applications have been increasing exponentially and creating new milestones with every advancement. In this century, we have many robots with intelligence equal to or beyond the human brain power. But my question about how robots do all the ingenious things, has led me to choose my personal project topic.

The inspiration for my topic has come from years of fascination. Pursuing the curiosity I have for technology since my childhood, I have always followed online articles like the IEEE (Institute of Electrical and Electronics Engineers) magazine. Due to which recently, I have been gaining interest in robotics and artificial intelligence, which adds more cognizance to the robots and I have been amazed by the advancements it has made in our world. Artificial intelligence interests me deeply because it is the technology of the future with a high potential of solving most of our planet's problems, leading to a better and more sustainable life. What I like the most about it is that there is a wide scope for creativity in this field, we can resolve a single problem in a variety of ways. Robots can prevent human loss in hazardous workplaces and in many situations robots can increase the work efficiency and the quality of the work in a minimum amount of time. These features of this field are the main cause of generating its interest in me. This is why although many different ideas came to light, after brainstorming, I set my learning goal to learn the fundamentals of robotics and artificial intelligence.



To enhance my knowledge about robotics, I always joined coding courses and robotics workshops every vacation. As seen from the certificates below, I have gained a strong base in coding that is the software part of robotics. But the hardware which involves the connections and wirings within the product is not something I am familiar with. But the whole concept of robotics, as I understand it, is the connection between the hardware and the software of the product. Therefore this learning goal challenges me to accomplish and master both these skills.

Global Context

I have chosen the global context of Scientific and Technical Innovation, particularly the impact of scientific and technological advances on communities and environments for my project. This global context comes from my belief that robotics and AI can change the world in revolutionary ways. My project is aimed to learn robotics and implement this knowledge into a product. I think that a global context like this would motivate my project as I would feel that I can do something for a better and safer world.

While researching, I felt very disheartened at the number of deaths and injuries caused by car accidents. Every year, 1.35 million people are killed on roadways around the world (CDC). The invention of cars is a pioneering idea but I strongly believe it is not worth these many lives. Since ancient times, there has been no clear functional protection or prevention of such mishaps in automobiles. It made me wonder if there were any solutions to these accidents and to make these vehicles safer. I think that there is a huge scope of enhancement in this automotive field by applying cognizance into the cars, we can facilitate safer commuting to places and save many lives. Thus this global context of Scientific and Technical Innovation has also empowered me to do further research in this topic for my product.

After researching, I found that according to a proposal by TU Delft to the Netherlands government, autonomous cars incorporating AI can become one of the safest cars in the world. These autonomous cars would be driverless and controlled by a specific software. This makes them secure and thus reduces the loss of human life as the leading cause of road accidents is distracted or sleeping drivers (WKW). Such innovation can also help disabled individuals to travel with ease without dependence on others. Adding to these features, these autonomous vehicles are also electric powered making them more efficient and sustainable (Robocar and Urban Space Evolution).

According to TU Delft, “These cars’ technological capabilities can provide solutions to pressing urban issues, such as growth, climate change, environmental quality, and the energy transition” (Robocar and Urban Space Evolution). Toyota has also unveiled a 2,000-person "city of the future," where it will test autonomous vehicles and robot-assisted living (CNN). This real-life application of this innovation is called the Woven City located in Japan. However, there are still improvements going on by researchers across the globe to make this idea prosperous. If all these researches come to a fruitful conclusion, we may see autonomous cars in the not too distant future.

Autonomous Vehicles, CNN, 8th Jan 2020

Product Goal

After thinking about such solutions, I decided to make my own prototype of an autonomous robot car using Bluetooth control, owing to my deep interest in designing or modeling. Although my robot car does not solve the entire problem of automobile accidents, it shall be a small and practical application of my learning of robotics.

Robotics is the connection of hardware and related controlling software, in my product the hardware would be the physical chassis of the car and the microelectronic devices like Arduino UNO, bluetooth module and motor driver, and the software would be the Arduino code which can be controlled via a Bluetooth app. I believe that my product is a small-scale model of these autonomous vehicles. Although my robot car is Bluetooth controlled and follows the app commands from my phone, these autonomous cars also have a similar idea of built-in locations and commands given by a particular software through a secure wireless medium similar to Bluetooth in my product. Similarly, my robot car follows the app commands from my phone and travels accordingly, in this way the entire vehicle would be in control like the autonomous cars which is the main aim of my product.

Success Criteria

To develop success criteria, I needed to prioritize the crucial requirements which define my product's success. For example, though a decorated physical design would make the product visually pleasing, like an outer covering, that is not the sole purpose of my product, which is to reflect my learning of robotics. The physical design would be quite basic with the hardware connections visible, this is also due to the cost criteria and to show how the connections work. Considering such parameters and through my initial research, I developed my success criteria often referring to the academic rubrics with level-wise evaluation and the FM ACCESS method in order to assess it in a variety of methods.

Criteria Type	**Level Descriptors**			**Justification**	**Testing Method**
	Level 3-4	Level 5-6	Level 7-8		
Function 1: My robot car must have accurate connections and wiring.	My robot car has poor connections due to which my car does not move.	My robot car has satisfactory connections to some extent allowing it to move frequently with few re-wirings involved.	My robot car has exceptional connections which allow the car to move freely without any obstacles.	Without accurate connections of wiring in a robot car, it is not possible for it to work. Connections highly determine the car's movement as they connect the hardware and software affecting the functioning.	The accuracy of the connections would be visually tested if the connections are incorrect, the robot car would not move in the first place.
Function 2: My robot car must travel at an appropriate speed.	The robot car moves at an extremely slow speed (less than 30cm/s)	The robot car moves at an adequate speed of 30 cm/s to 50 cm/s.	The robot car moves at an adequate speed of 50 cm/s to 1 m/s along with speed control.	An important aspect of any type of car is its speed. For a robot car, research says that the average speed of a robot car should be 1m/s to 3m/s however assuming that my robot car would be heavier due to the batteries used and the a	I would test the time taken with a stopwatch, and work out the speed, and then evaluate it.

				different structure, I have reduced it from 50 cm/s to 1 m/s *(RC Car - Robotics)*.	
Cost: My robot car must be budget-friendly.	The robot car needs an investment of between €150 to €200.	The robot car needs an investment of between €100 to €150.	The robot car needs an investment of less than €100.	Although the robot car should be professional, it should also be budget-friendly and should not require too much investment. From researching similar project reviews and materials online, I have found that it should need an investment of about €100 to €150. However, if it is less than €100, I would exceed expectations hence the level 7-8.	I would test this by evaluating the total expenditure required for the project and then test in which range it lies between.
Function 3: My robot car must follow the app commands via Bluetooth promptly.	My robot car obeys the app commands via Bluetooth but disconnects often and does not execute all the orders.	My robot car obeys the app commands via Bluetooth but takes time (greater than 3 seconds) to receive and execute the orders.	My robot car obeys the app commands via Bluetooth and executes all the orders in time (less than 2 seconds).	My robot must respond to the app commands promptly for easy use and time efficiency. After researching, I found out that the average response time is under 2 seconds *(RC Car Response Time)*.	I would test the average time from the moment of pressing the button to the instant the robot starts to move with a stopwatch.
Safety: My robot car must be safe to operate	My robot is safe to use but needs supervision while operating.	My robot car is safe to operate with insulated wiring and a protected battery.	My robot car is safe to operate with insulating wiring and a protected battery, with waterproof parts.	No matter how efficient the function and cost aspects of the car are, safety should be a priority especially since my robot car would have an electric circuit. The best safety precaution that can be done would	The safety would be tested by checking the insulation of the wires and the water resistance. The water resistance would be tested

				be to have insulating wiring and a protected battery along with waterproof parts.	on a separate wire used in the robot.
Material: My robot car must use durable rechargeable batteries that have a long battery life.	My robot car has a poor battery that drains within a day of use.	My robot car has a satisfactory battery life (less than 2 days) but the battery used is not rechargeable.	My robot car has an extraordinary battery life that lasts long (more than 3 days) and should be rechargeable.	The durability of the robot car should be long as it is impractical to switch new batteries frequently. The best durability would be attained when the batteries used have a long life and are also rechargeable.	Since there is no particular way to predict the battery life, I would test it by checking its rechargeability.

Figure 1: Success Criteria Chart

Action Plan

This action plan is an overview of all required goals and specific tasks for my product creation. Initially, I expected that the hardware required were easily available, but after researching, I realized that these materials would take more than 2 weeks to be delivered, and thus I had to change my plan accordingly. For the software part, I had to learn the C language which I had not included in my plan at first, which was challenging for me to finish learning within the due date. Thus I had to make many changes to my action plan. For each of my long-term goals, such as creating the blueprint and then joining the robotics class, I have set the deadlines after researching the approximate time taken to complete those tasks and then taking progress notes.

Action Plan				
Deadline Date	***Action to Take [Long Term Goal]***	***Tasks [Short Term Goals]***	***Relevant Success Criteria***	***Progress Notes***
22nd October	Finalize the required materials	• Complete the research of the materials required to build the robot	***Cost***	DONE
26th October	Purchase and order the required materials	• Order and borrow them from the available hardware stores for a reasonable cost	***Cost***	Deadline extended till 29th October, due to late delivery; DONE

31st October	Research the hardware connections between various parts	• Complete the research on the connections between the chassis and other components.	***Function 1***	DONE
5th November	Create a blueprint for the robot car	• Research the structure of the robot car • Create a blueprint for the robot car	***Function 1 and 3***	Moved to 9th November, due to illness; DONE
7th November	Join robotics class	• Take notes and record the session to review throughout the making	***Function***	DONE, attending every week
19th November	Finalize the structure of the robot car	• Finalize the connections and the wiring	***Function 1***	DONE
23rd November	Research coding the robot car	• Program the code in Python • Find an application easy to code and transfer the code into the robot car • Check the code frequently possibly with an expert for improvements	***Function 3***	Downloaded Arduino Version 1.8.19 Came to know that C language is used on this Platform DONE
1st December	Learn the C Language and Finish the code	• Find reliable sources to learn the C language fundamentals • Write the previous Python code in C • Check for errors	***Function 3***	Found the book “Let us C” Learnt coding in C and finished the code for the car movement DONE

11th December	Test the robot car	• Test the car along with the code • Check for any improvements in the robot	***Function 2 and Safety***	Moved to 16th December due to winter exams; DONE
13th January	Submit the final product to the supervisor	• Ask for any suggestions or questions		DONE, emailed questions to my supervisor

Figure 2: Action Plan

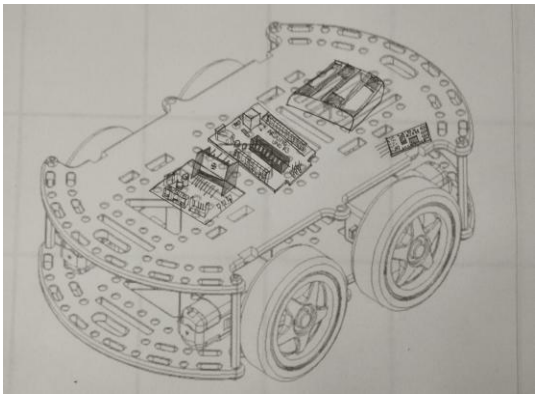


Figure 3: Initial Design of My Product

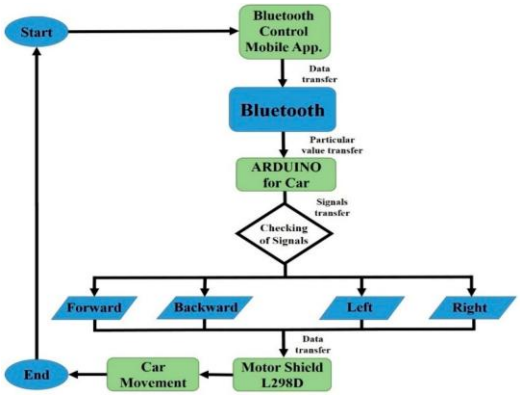


Figure 4: Design Flowchart of My Product's Mechanism

Criterion B: Applying Skills

Learning Goal: Communication Skills

As my project mainly required learning from the experts, researching, and troubleshooting errors with others, hence communication skills were highly necessary throughout. This was especially because I had joined a robotics club (Robotics Team Pi), which required a lot of communication as it is teamwork. Robotics Team Pi is a nonprofit organization, supported by the Netherlands government and funded by well-known software companies. Although the team was working towards international competitive robotics projects, I gained a lot of experience and received a lot of expert advice for my project as well. I had to display my communication skills by sending many emails, and messages and even setting up meetings with the experts in the team for guidance and a thorough understanding of the mechanisms and the concept of robotics.

I was also added to the Google Chats program, where I could ask my doubts and questions, this also helped me develop my communication. Every week a session was held practicing an example theme of the competitions, during this time my group and I had to give presentations to the rest about our ideas and perspectives. This allowed me to not only learn and explore AI but also to develop my communication skills. Answering the various questions in these sessions, I have also become a much better listener than before, which I think is essential in communication. Communication was also required with my project coordinator and supervisor via email to set up meetings and for asking questions about the report writing. This is why I think this project has provided a lot of opportunities to develop my communication skills a lot through this project.

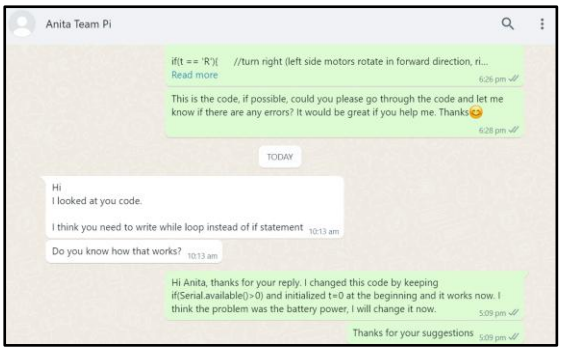


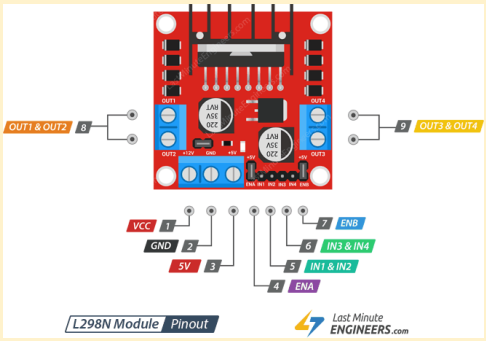
Figure 5: Communication Skills Evidence

Learning Goal: Information Literacy Skills

The path to achieving my learning goal entailed extensive research. It was essential for me to acquire further knowledge to gain a well-rounded perspective on the applications of robotics and AI in autonomous cars. By doing so, I would be able to accurately analyze and understand the various parts of an autonomous car and how robotics concepts are applied to them. From various sources, I have concluded that robotics is the connection between hardware and software parts. Thus researching these two concepts was essential for fulfilling my learning goal. While researching, I decided to make research notes including my conclusions, and analysis which would later help me in my product creation.

Hardware Part in Robotics

Source: "Interface L298N DC Motor Driver Module with Arduino." Last Minute Engineers, 2022, lastminuteengineers.com/l298n-dc-stepper-driver-arduino-tutorial/. Accessed 5 Dec. 2022.



L298N Module, Last Minute Engineer, n.d.

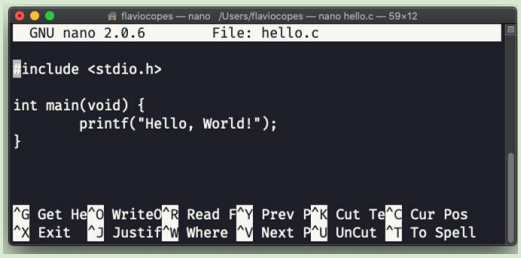
Excerpt of Notes:

- Power Pins: The L298N motor driver module receives power from two input power pins: VS and VSS.
- VS pin powers the IC's internal H-Bridge, which drives the motors.
- VSS is used to power the logic circuitry within the L298N and the rest of the microcontrollers.
- Output Pins: 4 output pins - Out 1-4
- The DC motors to these terminals are connected to these terminals.
- Direction Control Pins: IN 1-4 pins. These pins are connected to the Arduino Board, which has code encoded with direction control.

Input1	Input2	Spinning Direction
Low(0)	Low(0)	Motor OFF
High(1)	Low(0)	Forward
Low(0)	High(1)	Backward

Software Part in Robotics

Source: www.emeritus.org/blog/coding-arduino-programming-language/#:~:text=The%20Arduino%20programming%20language%20is,for%20beginners%20and%20non%2Dprogrammers. Accessed 5 Feb. 2023.



Copes, freeCodeCamp, 9th March 2020

Excerpt of Notes:

What is Arduino? Why is it suitable for robotic projects?

- ❖ Arduino platform is used to program microcontroller boards like the Arduino Uno
- ❖ The language is based on C
- ❖ Designed to be easy to use for beginners and non-programmers.
- ❖ Built-in serial communication feature - allows to communicate with other devices via USB.
- ❖ A special USB cable is used for connecting to the Arduino board and for transferring the code to the laptop.

Since this Arduino application uses C language, I also had to research the C language syntax and coding. Researching the syntax of the language was advantageous even in my product creation as the Python coding syntax, which I was familiar with, and the C language syntax were quite different.

Figure 6: Notes Excerpts

By creating research notes from gathering evidence, I was able to attain a better understanding of robotics and AI and how it is applied in an autonomous car. These reports were advantageous as they summarized research into digestible segments that could be used to expand my knowledge regarding the two main parts: hardware and software. During my research, I utilized both primary and secondary resources. I relied heavily on secondary sources for data and concept learning about AI and robotics. However, to become more familiar with this topic, I also used Team Pi as a primary source of information. I received live and meaningful information from the team as many of them are existing robotics engineers who have a strong background in robotics.

My research proved to be beneficial to my learning goal. Since every online source is not credible, I had to evaluate them using the CRAAP method as seen in Fig. 7. This procedure allowed me to recognize which sources were credible and conducive to my learning goal. From the research papers, prior knowledge, articles, and in depth concepts, I had attained a strong foundation in this concept to facilitate my product creation. Because of the depth of my research, I think that I have also improved in my research skills and I am more critical about my source than I previously was. This recently discovered knowledge and improved research skills superseded my expectation for the learning goal and gave me the resources needed to create the final product.

CRAAP Analysis Excerpt		
"Interface L298N DC Motor Driver Module with Arduino." Last Minute Engineers, 9 Mar. 2022, lastminuteengineers.com/l298n-dc-stepper-driver-arduino-tutorial/.	C - The information was posted in March 2022. The information has been updated recently. I believe that this topic of hardware connections does not entirely require current information as it is not an ever-changing topic, old sources would work as well. The links are functional and accessible.	Recorded full notes as a separate document entitled “Personal Project Research Notes” **Notes Excerpt:** ● <u>Power Pins:</u> The L298N motor driver module receives power from two input power pins: VS and VSS. ● VS pin powers the IC’s internal H-Bridge, which drives the motors. ● VSS is used to power the logic circuitry within the L298N and the rest of the
	R - The content within this source is relevant because it answers my question about the various pins in the motor driver. This is the exact information I required for my learning. I have looked at a variety of sources before settling on this one, and I would be comfortable citing information from this source in a research paper.	
	A - The author of this source is a credible, non-profit organization called Last Minute Engineers. The source offers contact information for the reader (email and feedback form)	

Accessed 5 Dec. 2022.	and establishes itself as a credible source with all rights reserved.	microcontrollers. ● Output Pins: 4 output pins - Out 1-4 ● The DC motors to these terminals are connected to these terminals. ● Direction Control Pins: IN 1-4 pins. These pins are connected to the Arduino Board, which has code encoded with direction control.
	A - The information is provided by Last Minute Engineers and they endeavor to keep the information up to date and correct. The content is used and is given positive feedback from other users. The information is also unbiased, objective, and free from any typographical errors.	
	P - This information informs the audience about the various parts in the L289N Motor Driver. Their objective is to teach about the Motor Driver and its parts in depth. Since this is general technical information, it does seem impartial.	

Figure 7: CRAAP Analysis

Product Goal: Affective Skills

I believe programming is such a precise task where a single unnoticed semicolon can cause the whole code to crash. Being just a beginner in C language I felt like giving up on my project at times. However, throughout this project, I have practiced managing positive thinking and I have specifically learned to deal with stress while analyzing and attributing causes of failure. Although there were one or two disappointments I was unable to meet my expectations on the first try, I have learned to deal with these and maintain a positive attitude and took a rest for better results. For example, this was one of the reflections in my process journal where I feel I had applied my affective skills the most:

"One of the problems I often faced was when the code was accurate and the hardware connections were correct but my robot car still wouldn't work. I had troubleshooted for errors repeatedly yet there was no response from my product. However, I tried my best not to be stressed and took it positively and reminded myself that failure is a part of learning. I reviewed my code, made changes, and tried again yet it didn't work. It took me a lot of time and thinking to find out the problem, however, I was glad that I maintained a positive focus on my project and I believe that has helped me in solving the problem. I kept this positive and preserved behavior throughout this project because I was passionate about my topic and wanted to learn more. After applying some critical thinking, I understood that the problem this whole time was the power supply and switched to another stronger battery of 9V from the previous 6V, and this time it responded and moved according to the signals!"

One of the ways I practiced affective skills was by taking a break when things were not working well. These short breaks proved to be quite beneficial as they gave a fresh perspective to think from after taking some rest, thus helping me analyze the problem carefully. Researching the possible problems on online forums also made me bounce back and motivated me to work on the project again as I understood that it wasn't only me facing these problems and that such obstacles happen and can be solved.

Therefore, despite failing many times, I tried a lot to preserve it and kept going until it worked. This overall experience made me more confident in my learning of robotics and made me practice "bouncing back" after adversity, mistakes, and failures. I believe I have developed my affective skills through this project quite effectively. This was especially so because, at the start of the project, I used to easily get disappointed when something didn't go as planned and easily got dispirited by failures. But now, I see a lot of improvement in me in this skill through this project.

Product Goal: Critical Thinking Skills

As mentioned before, programming is a very precise job and critical thinking is highly necessary to identify the error. Thus while I was working on the project, these critical skills were useful to troubleshoot why something didn't work or even understand why a certain approach did. For this, I had to develop a lot of flexible thinking

which involves considering multiple opposing and contradictory arguments. I had to think of all the possible causes of the problem with my product, which involved thinking from different perspectives and looking at the bigger picture to see what may impact its functioning.

For example, when my code was not working with the app I was using, I decided to draw a mind map of possible errors, then for detailed and organized troubleshooting I created a table with the applicable cause, effect, and solution to solve the issue as seen in Fig. 8&9. Such brainstorming aided me in having a clear and organized approach to analyzing and solving the problem. After doing so, I made circuit diagrams of the connections and changed them to see their impact on the robot car, helping me further analyze them. Using these methods, I checked and eliminated each possible problem that could have been in the car and concluded it was due to the lack of energy supply which I had solved by increasing the voltage of my batteries. Therefore I think I have used my prior knowledge of troubleshooting as well as applied my understanding of my learning goal to think critically about my product. Although I have always had the spirit to think about problems critically and find out their solutions regardless of their difficulty, this project has made me grow a lot in this skill. I have learned ways of organizing my thoughts and approaching the possible problems of the product by applying the knowledge I have acquired through my learning goal.

Is the cause solved?	Possible Cause	Effect	Possible Solutions
☑	Batteries (6V)	The weak energy supply is not enough to power the robot car	• Batteries of 9V • Attach power bank → Too heavy for the robot car to drive with • Power through USB cable of the laptop
☑	Hardware Connections	A minor disconnection in the circuits in the robot car could cause it to not work	• Check all the connections again • Remove all wirings and do it again. • Check the soldering of wheels and motors
☑	Code	Incorrect code can cause this disconnectivity between the robot car and app used	• Double check for syntax errors • Run through each section of code and identify the errors.
☑	Code and App Incompatibility	The Bluetooth connected app is not compatible with the coding language used in Arduino (C Language)	• Try to code in Python or C++ • Change app
☑	Arduino Application Version	Lastest updates may contain bugs which are not discovered yet or not stable	• Download a stable version of Arduino

Figure 9: Critical Thinking Table

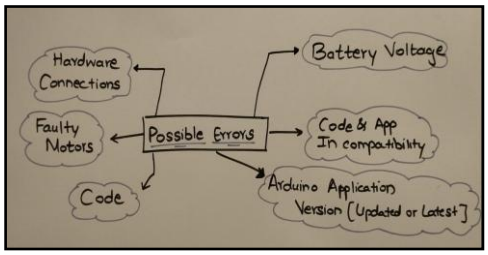


Figure 8: Critical Brainstorming

Criterion C: Reflecting

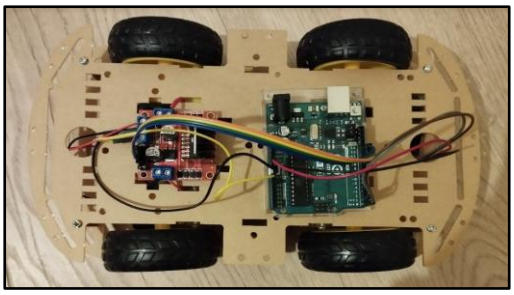
Final Product Evaluation

Please refer to Fig.1 Success Criteria Chart. The Criteria Descriptions below are of level 7-8.

Function 1: My robot car has exceptional connections which allow the car to move freely without any obstacles.

My robot car has exact and accurate connections which allow the car to move freely without any obstacles. The car does not require any rewiring due to loose connections or wrong connections, which makes the motion of the robot smooth without pausing in the middle. The connections are also aligned with the code and follow the exact directions. This is evident when the forward button is pressed in the app, the car moves forwards and not backward. The hardware connections are also organized as the wires are not tangled, are clear to follow, and do not interfere with the wheels during motion. Overall this exceeded my expectations which is why I think for this

criterion my product deserves an 8.



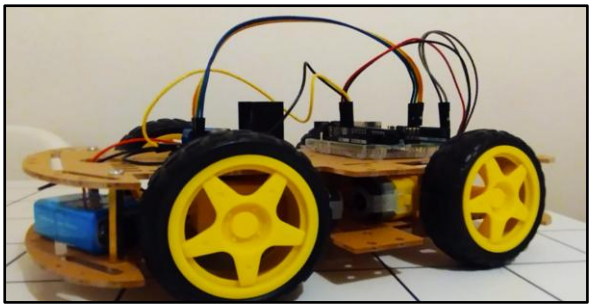


Figure 10: Connections Evidence

Personal Project Budget	
Item	Price
Arduino USB Cable	€2.03
Jumper Wires	€5.00
Bluetooth Module	€6.93
9V Batteries	€19.53
9V Batteries Clips	€6.93
Arduino UNO Rev3	€17.50
H-Bridge Motor Driver	€10.79
Soldering Iron Set	€14.99
4WD Robot Chassis	€15.99
TOTAL	€99.69

Figure 11: Budget and Expenses Evidence

Cost: The robot car needs an investment of less than €100.

As seen in the evidence, the total expenditure on the product was €99.69, which is slightly less than €100, this was the total cost of the components in the product. I have tried to scrutinize and research a lot to get the least expensive and good quality products online and also borrowed a few parts from friends. Initially from researching similar project reviews and materials online, I found that it should need an investment of about €100 to €150. Hence as it was less than €100, it is considered to exceed expectations. However since the total expenditure was slightly less than €100, by 21 cents to be precise, it hasn't completely superseded the expectations of my budget which is why I think a grade 7 is appropriate for this criterion.

Function 2: The robot car moves at an adequate speed of 50 cm/s to 1 m/s with speed control.	**Grade: 6**

As seen from testing, my car takes 2.07 seconds to travel 1 meter, hence the robot car moves at an approximate

speed of 48 cm/s ($speed = \frac{distance}{time}$). Although this is a satisfactory speed which is enough to see movement, it doesn't really supersede my expectations. Reflecting back, I think the car could've moved faster if the hardware and the battery were lighter; however, this was only noticed after the entire product was made and would be difficult to change. Although there is no specific separate device for speed control, when the control buttons on the app are pressed with more pressure, the robot car moves faster. Hence there is a sort of speed control present but not a sophisticated coded device for it. However, it has met my expectations which is why I think a 6 is appropriate for this criterion.

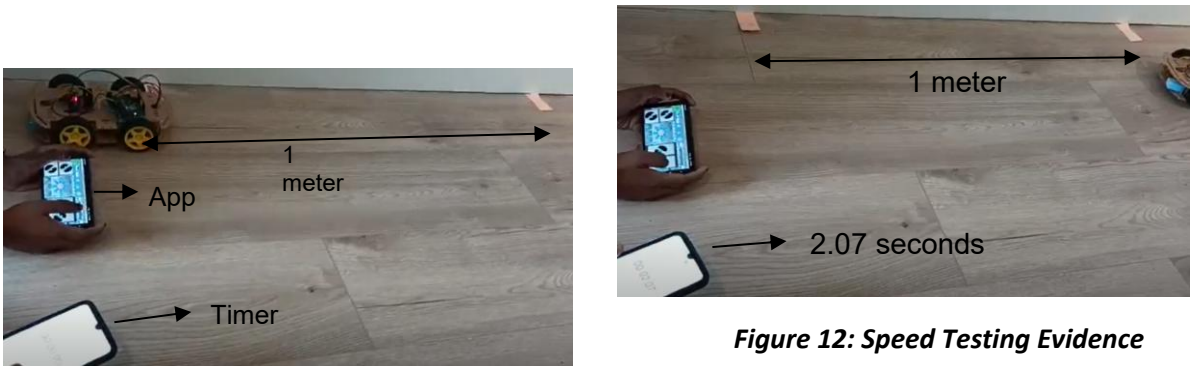


Figure 12: Speed Testing Evidence

Material: My robot car has an extraordinary battery life that lasts long (more than 4 days) and is rechargeable.

My robot car's battery is easily rechargeable and is charged in less than 3 hours. The battery also lasts up to 5 days. I have tested this criterion by looking at online reviews of the battery's life. I have also tested it out myself by leaving the battery without charging and testing it every day. With this testing method, I found out that the battery has a battery life of more than five days as it had stopped working on the fifth day. This was expected as it was a huge part of my budget. Hence after applying proper testing methods, my robot car has a long battery life and is rechargeable, which meets the criterion according to my success criteria. grade 8

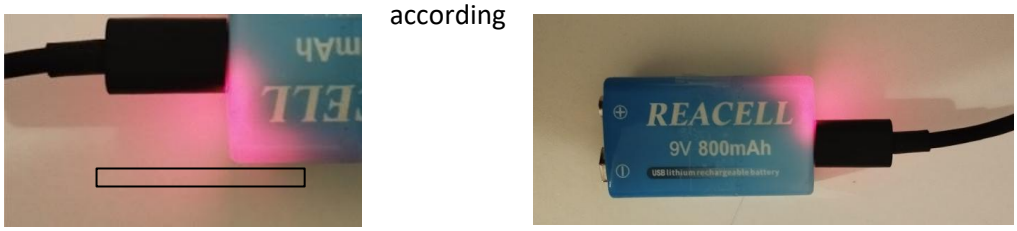


Figure 13: Rechargeable Battery Evidence

Function 3: My robot car obeys the app commands via Bluetooth and executes all the orders in time (less than 2 seconds).	**Grade: 7**

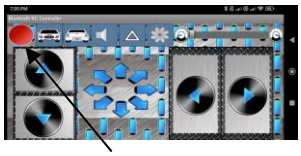
My robot car follows the command of the app, "Bluetooth Control RC" while it is connected to Bluetooth via the HC-05 module. It responds quickly to these orders and executes them in about 1 second, which is less than the time expected in the criterion. The app also connects to the robot car in about 2 seconds however, this is dependent on the distance as the BlueTooth can be connected only in a certain range. Moreover, the app is not created by me but downloaded from another source. This is because it was not mentioned in my criteria and I was not aware that we could create apps easily via MIT App Inventor. This is why, although the robot car does

connect to the car instantly and executes the orders in less than a second, I think to exceed expectations I had to create my own app. Thus, I think my product should be given a 7 for this criterion.

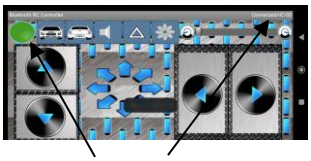
Figure 14: App and Device Connection Evidence

Safety: My robot car is safe to operate with insulating wiring and a protected battery, with waterproof parts.	**Grade: 6**

My robot car has been tested to be safe to operate with insulated wiring. All of the wirings are of great quality and have a complete insulated covering, leaving no chance of a short circuit. The battery is well protected and also taped to the chassis of the robot car for contact prevention. However, the robot car is not waterproof. The wires are insulated, but the microcontrollers like Arduino UNO and the BlueTooth module would not work if submerged or contacted with water. Therefore the robot car does not contain completely waterproof parts. This could have been fixed if such waterproof parts were purchased which are quite expensive and could not be considered due to the cost criterion. It is also possible if the height of the robot car or the distance between the two bases is increased, doing so only the wheels of the car would be in contact with the water, but this would require a different chassis for the car which is rarely manufactured and available in shops. Hence due to the lacking waterproof parts, I would give a 6 for the product in this criterion.

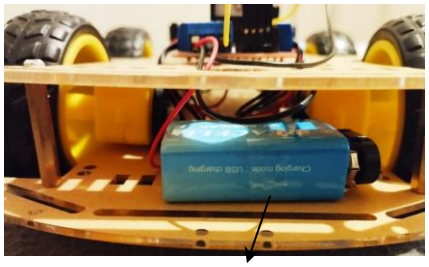


Not connected



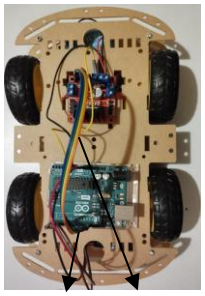
Connected

Robot Car's Bluetooth Module



Battery placed in the chassis of the car (Contact prevention)

Completely insulated wires



All the surface in contact is insulated

Figure 15: Safety Precautions Evidences

Overall Product Evaluation

According to my success criteria and evaluation, I think that my product is quite successful and is in the 7-8 level. In order to assess my product according to the market standards, I sent my product and success criteria to be evaluated to two ASML engineers who work in the electronic and mechanical fields. As seen on the right, the feedback I received was very positive and encouraged my learning goal. The engineers appreciated my idea of using Bluetooth to control the device and the speed of my robot car. Their appreciations and the success of my product has motivated me to learn more about this field in my future as well. Getting feedback from external and experienced engineers has helped evaluate my final product according to the industrial standards. Thus from my evaluation and the feedback received, I give my final product **a grade 7**.

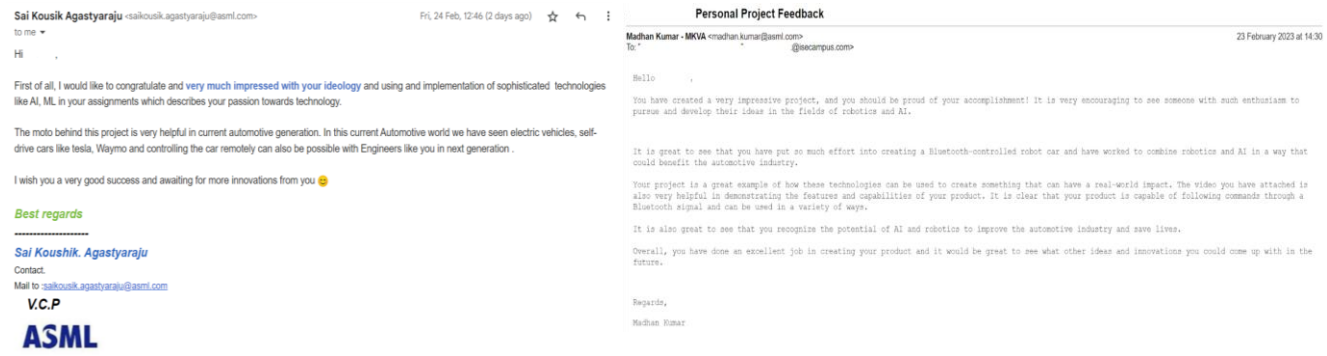


Figure 16: Feedback from ASML Engineers

Impact on my learning

This project was a great learning opportunity and has helped me fulfill my learning goal to a great extent. **Most prominently, the main skill I have achieved is learning the C programming language.** The C language is the main language used on the Arduino platform to code. With my python programming and other coding knowledge, I was able to grasp it fairly quickly. C programming is a widely used and essential language in programming, hence it is a practical and beneficial addition to my skill set.

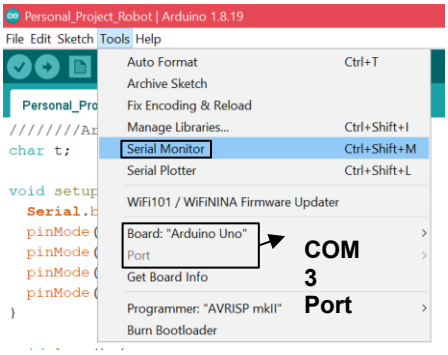


Figure 17: Arduino Application

I also explored the **Arduino application** a lot. I have looked through various options in the application and enquired about their functions. For example, when my robot car was having problems working, I looked at my settings and the selected options in the Arduino. I had found a way to check if my car was receiving signals from the app, which is seen in the Serial Monitor of the platform as seen in Fig. 17.

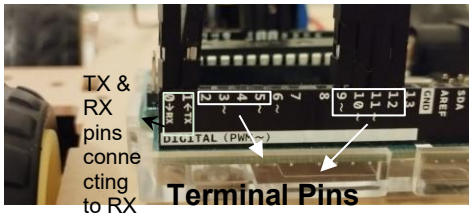


Figure 18: Arduino UNO Hardware

The main addition to my skill set was learning how to **connect** the various components and microcontrollers together in the robot car. I got the chance to learn and understand why connecting wires to a a particular part works. For example, in the robot car, I learned that we should always connect the TX and RX pins

of the Arduino board to the RX and TX pins of the Bluetooth module only after uploading the code into Arduino. I also learned such things by experimenting, for e.g, I switched the four terminal pins on the Arduino board from (9, 10, 11, 12) to (2, 3, 4, 5) and came to know that the selection of these pins does not matter as long as the same pins are used in the code as seen in Fig.18.

The project also helped me develop **my hardware and electrical skills**. The major section of my product apart from coding was the hardware connections in my product which had to be made using my technical skills.

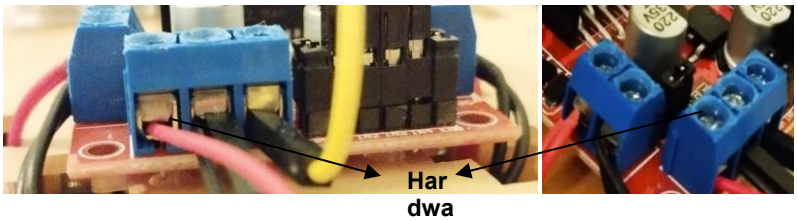


Figure 19: Hardware Skills in Motor Driver

I also learned to solder the wires to the motors of the wheels which is a very delicate task requiring many safety measures. The connections in the motor driver were the most challenging part as wires with minuscule diameters had to be placed into a comparatively large pin of the motor driver and then screwed down. This task required great concentration and precision to do it successfully. Often at times, I would screw the pins down, but the wire would still come loose as seen in Fig.19.

Impact of my product on myself

The IB MYP project helped me develop a multi-tasker mindset. I think this process has prepared me for my Diploma and my future engineering career as it has taught me the importance of effective time management, action plan creation, critical thinking skills, and technical skills for my career. Through participation in the IB MYP Project, I also grew into an inquirer. With my chosen project, I researched deeper than necessary because I had a passion for robotics and a belief in its significant capabilities. Now, I am more open to exploring the intricate details of a topic to conclude and decide on solutions and projects. This project has motivated me to be more research-oriented and contribute to such studies as a part of my future education.

This project has made me more organized as I had to manage my time effectively for both my academics and the project. I made schedules and kept alarms to keep track of time to finish my final product, and now even after I have completed my product, I have adapted the habit of making a schedule for the day whenever I sit to study. It helped me develop critical thinking skills and to approach a problem in different ways and think creatively while doing so. This critical thinking skill will be quite useful even in my future endeavors.

The Personal Project Exhibition was a great experience for me. This was because the communication skills I had acquired and developed during the process of my learning were very beneficial when presenting my project. I observed that I was able to explain my product and my global context more confidently than before and this interested many people to look at my project. I had a lot of positive feedback from parents and teachers, increasing my confidence in my chosen topic. Many people also controlled my robot car successfully using the app, implying that it is user-friendly and can be used easily without any background knowledge.

During the exhibition, I also learned to handle issues spontaneously. My robot car's battery drained on that day due to the car being switched on for a long time and I had to charge it on the spot. One of the wires connected to the battery also came loose during the process of charging and I managed to fix it during the exhibition using a screwdriver which I had packed in case of such incidents. I think I have also developed such spontaneous management skills which is a useful skill during live events like this. Overall, it was also pleasing to see that robotics and AI-related solutions are becoming more welcomed by people. However if there was something I would do differently, I would have made my poster and my stall a bit more visually pleasing.

As mentioned before, my project is a prototype of a fully functional autonomous vehicle. In the real-life scenario, companies like Tesla, Toyota, Volkswagen, etc. have already implemented this concept successfully, however, they are still investigating to overcome some limitations by adding more advanced features like complete software control without human intervention, obstacle control, and cloud-to-vehicle information transfer. They are still working on this cloud data idea because of security issues like hacking the vehicle's control system. My hope and opinion is that in the following few years, we would have many other 'Woven Cities' with autonomous vehicles moving safely on the roads every day.

Woven City Tokyo, CNN, 8th Jan. 2020

Lastly, with many technical universities and car companies researching this revolutionary concept of autonomous vehicles, I endeavor to contribute to this idea myself in the future with the motivation of my personal project.

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