Theory of Science

Written Assignment

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1 Introduction

In this essay I present my experiences in team projects and apply some of the concepts learnt in the philosophy of science lectures. As I am an exchange student at SDU, I have decided to use a similar project module to *Expert in Teams* named *Product Development*. The course focuses on creating a concept to solve a specific problem in the third semester and to realise the concept in the fourth semester. This essay reflects on how different reasoning methods were applied during the project work and how philosophical concepts describe the group's influence on the project's outcome.

2 Waste Collection and Filtering Robot

In *Product Development* (PREN), teams of six students develop a device that has to solve a specific task and then compete against other teams at a small competition. Each team has two electrical engineering students, two mechanical engineering students and two computer science students. The assignment for each group was to create an autonomous garbage picking robot. Bottle caps, plastic caps, cigarette butts and keys were spread across the work field and the robot was required to collect these autonomously. The robot itself is mounted at a stationary location adjacent to the work field and therefore required an extendable contraption to reach as much of the work field as possible. Our group decided on a SCARA (Selective Compliance Assembly Robot Arm) consisting of three movable segments, a Z-axis and a grabbing mechanism (see Figure 1). Unfortunately, due to a lack of time, the robot could not be completed, and other groups fared similarly, with a few exceptions.

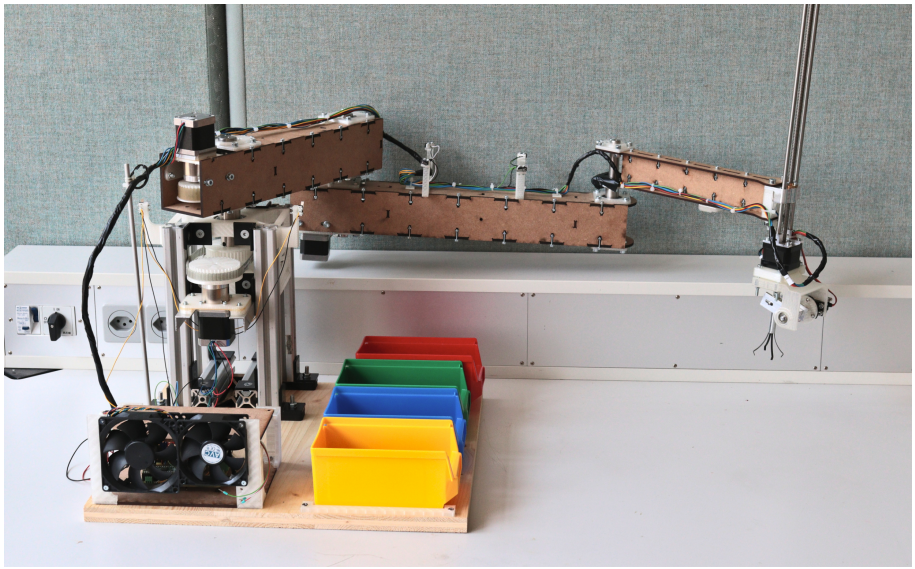


Figure 1: The PREN robot

In the first semester, time was spent on understanding each other, specifically what abilities and personality each member can bring to the team, and creating the concept of the robot. Unfortunately, in the first six weeks a lot of time was lost in the problem breakdown and task assignment phase. It was forgotten to establish the actual expectations and the resulting "true" personalities of the individual members. The absence of a clear understanding of each other's expectations resulted in

organisational challenges and unclear project expectations. The consequence was confusion among each other, since there is no baseline in the team. An appropriate concept to describe this scenario would be the fundamental attribution error [1], as it seemed that everyone thought the project would work because everyone would have the same expectations, which was not the case . There could also be a thematic connection with Francis Bacon's *Idol of the Cave* [2]. The individual team member might have operated "in their own caves" of subjective perceptions, assumptions, or biases, which hindered effective communication and collaboration. The issue was solved by clarifying everyone's expectations, restructuring the team and assigning the main roles such as project leader to the fitting members.

Communication and behaviour across group has shown various parts from Bacon's Idols [2]. The *Idols of the tribe* were identified after analysing the team discussions during the planning phase of the project. Everyone had a different picture of the same idea, which led to misunderstandings. As a solution, The person who suggested the idea was commissioned to sketch the idea. Since the project and, in particular, the implementation process of our chosen idea required a great deal of effort, which not everyone was able to contribute equally, there were work conflicts and contentious discussions. This could be due to the amount of time involved or the expectations among the members, but it certainly seems to fit the description of the *Idols of the Cave*. The passion, devotion and enthusiasm did not line up with the others and therefore brought conflict. This was improved by giving each other enough space to deal with the issue first before starting discussions and finding a compromise. PREN encourages students to acquire new knowledge themselves. They are tasked to familiarise themselves with the content of new concepts, such as inverse kinematics or the MQTT protocol. These concepts were assessed using simulations with CAD or mathematical software. Characteristics of Bacon's *Idol of the Theatre* were recognised in retrospect in this process.

The writing of the concept and the implementation in the second semester uses both scientific and engineering methods, which are shown in Figure 2. The project assignment is based around a problem: garbage needs to be picked up and automatically sorted based on their type. This problem is more suited to the engineering method in Figure 2a, as it is a practical challenge requiring a solution. The scientific method in Figure 2b also has its uses in the engineering method. Designs need to be tested on their physical attributes, in which the hypothesis corresponds to the desired test conditions or results. Figure 3 shows an idea on how the scientific method could be used in an engineering method.

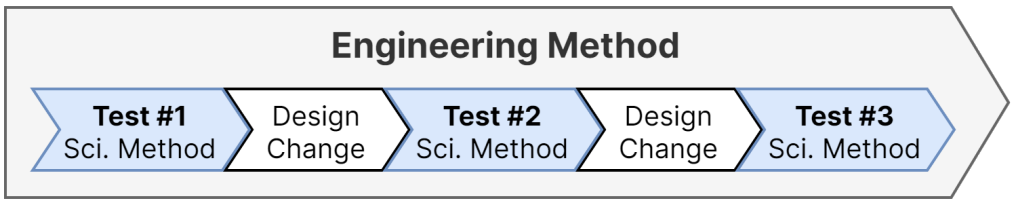
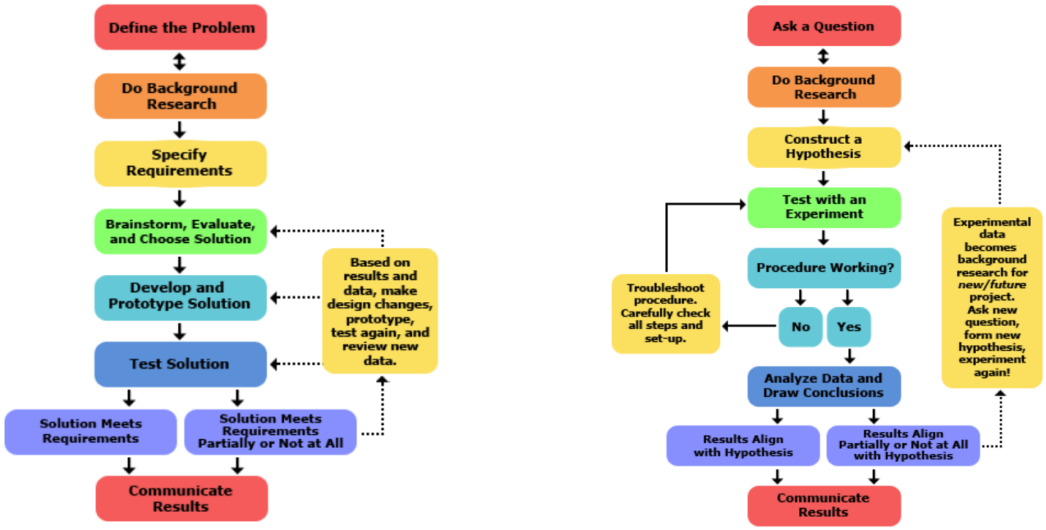


Figure 3: Idea on how scientific method is used in an engineering method based project flow

After reflecting on the groups approach by applying the three philosophical methods of reasoning [5], all three types of reasoning could be found in some form in the work – specifically, inductive and abductive reasoning. Inductive reasoning was used for testing the mechanical parts using stress



(a) Engineering method [3] (b) Scientific method [4]

Figure 2: Diagrams of the two methods

testing. One of these tests was the durability and flexibility test of the main material used for the encasing of the arm. The material was conditioned under the maximum defined load and additionally subjected to tension and compression. PLA, wood and acrylic glass were considered for this test, with wood emerged as the most favourable option. Drawing on the background knowledge from mechanical engineering and physics classes, a general model of the arm segments could be extracted or validated from the test results.

Abductive reasoning was mainly used when one was not familiar with the concept of a physical process. For example, it was assumed that the stepper motors used in the robot emitted thermal energy, but due to their discrete movement, the temperature change was generally neglected in the calculations. Fortunately, this worked out fine.

Deductive reasoning was used for testing the electronics, involving the firmware and hardware. In general, electronics design employ the deductive reasoning approach, as misuse or abuse of electronic components can lead to fatal injuries, and component calculations are based on their derived models. An example would be determining the reference voltages for the maximum current for the motor drivers. The voltage was initially calculated using an equation provided by the manufacturer and verified during the commissioning phase using a multimeter and by observing the stepper motors' behaviours.

The firmware (code for embedded systems) utilises a combination of inductive and deductive reasoning. Deductivley, the code structure was planned first using flow charts and state diagrams, before being translated to actual code and tested on the hardware. By testing the code on various preset conditions, bugs can be identified and fixed, representing the inductive reasoning of actively updating the code based on the test results. The same applies for the software written by the computer science students.

As I mainly worked on the firmware part of the project, I wrote code naturally with *René Decartes' four rules of thinking* [6] applied. Especially rules two "break every problem into smaller parts" and

three "solve the simplest problems first" were employed to split up a components code into sub components and to create clean code structures. The *split-up* design allows for easier lookup of specific code lines and for solving bugs and errors. Rule four "be thorough" found its use in writing the code documentation, as explaining clearly how features function was essential for the reader's comprehension of the code. Lastly *Mill's method of difference* [7] and logical thinking were used for debugging code. If a new iteration of a function causes an error, the error can be derived from the fact that the error did not occur in the previous iteration, but in the new iteration. This narrowing down aids in narrowing the scope to the location of the bug.

3 Conclussion

This essay shows that scientific and engineering methods as well as philosophical concepts are always present in some form in project work. From my own reflection, I noticed that several concepts were passed on to me, unknown of their origin and meaning, whether verbally or through literature. Once a term has been associated with these concepts, it is easier to recognise them or apply them in new projects. In addition to raising awareness, it helps as additional information in discussions about the history of science, for example.

The three reasoning methods can used for conveying the logic and method of experiments in form of texts without the need of lengthy paragraphs. In regard of the course *product development*, it made it possible to retrospectively label certain processes with the appropriate term and improve understanding of why certain scenarios occurred.

Recognised concepts such as Francis Bacon's four Idols of the Mind, the fundamental attribution error and René Descartes' Four Precepts has additionally helped with analysing certain behaviours from not only myself, but also from the group. While there are concepts not applied in this essay such as the availability heuristic [8], explaining that we often misjudge the frequency and magnitude of events due to our limitations of memory and that we remember things better through vivid narrative, and the hindsight bias [9], they still deem useful for future use.

While this essay delves into specific methodologies and concepts, it is important to note the relevance of concepts such as the availability heuristic [8], highlighting our tendency to misjudge the frequency and magnitude due to the limitations of memory, and the hindsight bias, emphasising the "knew-it-all-along" effect when looking backward in time and see events as more predictable than they actually were [9].

In terms of ethical engineering, the project was questionable, not because the robot could cause injury, but because of its usefulness. Waste is not only a social problem, but also has an impact on the environment. Microplastic harms wildlife, such as the plastic consumption of aquatic animals. As a personal opinion, the view that society must be forced to dispose of its own waste simply does not take all human factors into account. Conflicting opinions or other views may lead to waste not being disposed of appropriately or the options may not have existed in this situation. The robot solves an environmental problem, but not completely. An idea would be to make recycling and sorting waste more attractive and allow for robotic assistance.

4 References

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