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INVENTING AND PATENTING USING HALF-CAUSATION: NEW PHILOSOPHICAL TOOLS FOR ENGINEERING DESIGN EDUCATION

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ABSTRACT

This paper has two objectives. The first is to briefly introduce a readership in Engineering Design education to Half-Causation, which is a philosophical model for inventing and patenting. Following a brief introduction, Half-Causation will be illustrated using the well-known case of the centrifugal vacuum cleaner, which was invented by the British inventor Sir James Dyson in the late 1970s. The second objective is to present the outcome of a 3-hour workshop which took place at the University of Bristol in 2021, in which doctoral engineering students were introduced to Half-Causation, before being given an engineering design problem to solve using it. The problem was 'how to reduce the probability of a cyclist unseating (flying over the handlebar) when braking at high speed.' Instead of addressing the problem in the traditional terms of morphology or functionality, the participants were encouraged to focus on *causal properties*. The participants were divided into four teams, and they clearly got a reasonable grip on *Half-Causation Branching* and followed its instructions faithfully. The four teams developed 44 inventive concepts, albeit some of the same or similar inventive concepts were developed by multiple teams. The workshop ended with discussing the optimisation of the scope of sought patent protection, using *Half-Causation Encapsulation*. The paper concludes by recommending adding the Half-Causation tools to engineering curricula, both in terms of generating ideas and intellectual property, specifically patents.

Keywords: Inventions, patents, half-causation, engineering design education

1 INTRODUCTION

Abolkheir 2019 presented 'Half-Causation', which is a philosophical model for the systemisation of the process of *inventing*. [1] Abolkheir 2021 addressed how to optimise the process of *patenting* [2]. This paper has two objectives. First, to briefly introduce a readership in Engineering Design education to Half-Causation. The second is to present the outcome of a 3-hour workshop which took place in 2021, in which doctoral engineering students were introduced to Half-Causation, before being given an engineering design problem to solve using it. The workshop was the first at doctoral level, and progressively followed on from earlier undergraduate workshops, and patent-developing collaborations with students and academics. It is worth briefly highlighting where Half-Causation is positioned within the different intellectual attitudes towards creativity. We have those in the early 20th Century who argued that creativity is mysterious and resistant to structuring e.g., Popper [3]. Then we have the different approaches to systematic design which gradually emerged decades later including functional analysis, morphological charts, TRIZ and C-K; see for example [4] & [5]. Half-Causation sits within the systemisation efforts, while benefiting from solid philosophical grounding and from strategically targeting patentability.

2 HALF-CAUSATION

Half-Causation consists of five phases of reasoning, each terminating with taking a 'logical branch.' In the first instance, Half-Causation is a descriptive generalisation of how technological inventions have been developed in the past i.e., engineers and scientists (and inventors generally) could be seen to have developed their technological inventions using something like Half-Causation, albeit partly consciously and partly not, and partly efficiently and partly not. The abstract tools of philosophy were used to isolate and articulate the inventive reasoning involved, before presenting it as a *prescription* which can be followed in future invention projects to systematically develop inventions. Half-Causation as a method is named after its first phase which consists of a methodological idealisation of the causal process, by pinpointing *half* of a possible causal relation while ignoring everything else. Following this, Half-Causation prescribes how the reasoning should proceed, which ultimately constructs a complete and novel causal process. In non-technical terms, Half-Causation captures the reasoning from a technological problem towards multiple possible solutions, or from a technological solution towards multiple problems which can possibly be solved by it. [1] [2]

2.1 The Half Causation Phase

This phase consists of the pinpointing of *half* of a possible causal relation, which can either be:

- A **Distinctive Causal Input ['DC Input']** which is available, but for which some desired Distinctive Causal Output ['DC Output'] is sought i.e., there is *a technological opportunity*.

Or

- A **Distinctive Causal Output [DC Output]** which is desired, but for which some available Distinctive Causal Input [DC Input] is sought i.e., there is *a technological problem*.

2.2 The Domaining Phase

At this phase, the half-causation (be it a DC Input or a DC Output) is domained in a specific technological area/arena, within which a matching half-causation might be found (at the next phase). The Domaining is done by figuring out what would happen in the middle of some causal process or another. The history of technology has shown that many great inventions were developed following novel domaining which occurred at this phase.

2.3 The Matching Phase

At this phase, the half-causation gets matched with some other half, both of which belong to the same technological domain. So, if the half-causation was an available DC Input, then it gets matched with a desired DC Output. But if the half-causation was a desired DC Output, then it gets matched with an available DC Input. It is at this phase that the inventive concept is clinched i.e., some in-principle understanding of the causal process: what DC Input would be present at the beginning; what would happen in the middle; then what DC Output would emerge at the end.

2.4 The Essentialisation Phase

At this phase, the essential details of the causal process are identified and synthesised. The term 'essentialisation' reflects the fact that it is the synthesis of the DC Input, the DC Output and the *essential* physical conditions that constitutes the invention and confirms that the match actually works. The essentialisation can be physical or analytical. It is important to note that until this phase is terminated there is no invention yet. If patent protection is sought, then the information that is generated at this phase would be helpful in preparing a patent application.

2.5 Accessorisation Phase

At this phase, the essentialised match between the DC Input and the DC Output finally gets accessorised by adding *accessory* physical conditions. These features are deemed 'accessory' because they are not 'essential' for the invention. This phase terminates with the generation of the first industrial product design which incorporates the essentialised DC Input-DC Output match. The termination of this phase constitutes the end of a given invention project. All subsequent activities e.g., the generation of other product designs, or achieving business and financial successes fall outside the scope of Half-Causation.

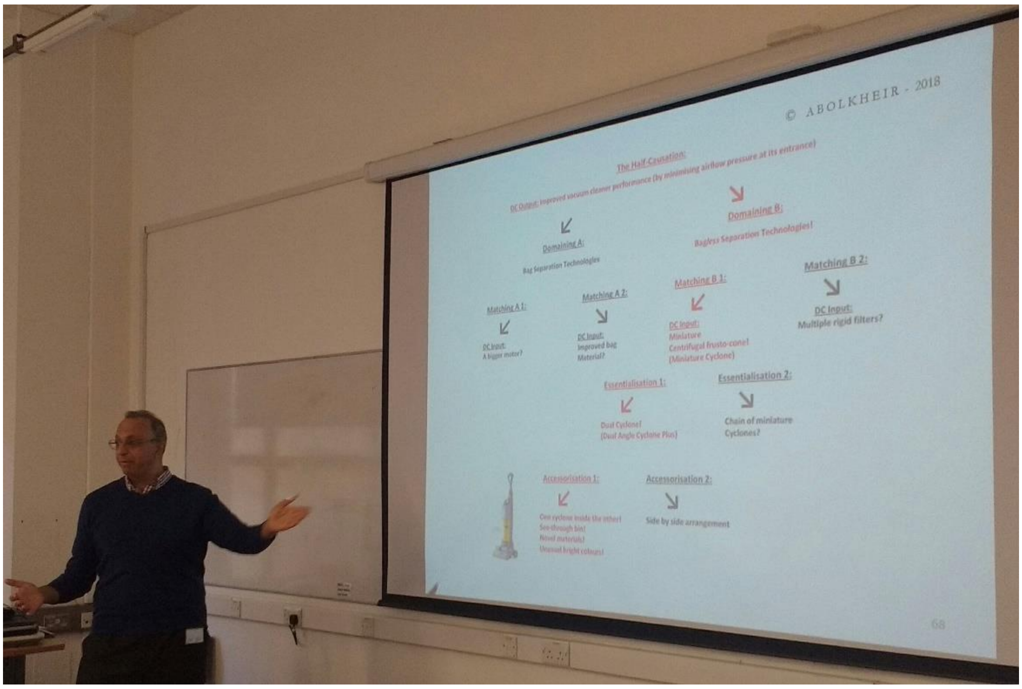

Figure 1. Mo Abolkheir presenting the Dyson case at a face-to-face Half-Causation workshop in 2019

3 THE CENTRIFUGAL VACUUM CLEANER CASE STUDY

This invention was triggered by a technological problem. James Dyson (now Sir James Dyson) recognised that the vacuum cleaner bag gets clogged soon after first use, causing a loss in pulling-in power. A vacuum cleaner works by creating airflow pressure that is lower than atmospheric pressure, and as such pulls in dirt-laden air. So, the desired DC Output was improved vacuum cleaner performance, by having airflow with minimal pressure at the entrance of the vacuum cleaner. [1] [2] [6] [7]

- So, at the end of the Half-Causation phase, the DC Output was identified as improved vacuum cleaner performance, by having airflow with minimal pressure at the entrance of the vacuum cleaner, and that finding some DC Input that causes it was deemed in principle technologically possible.
- At the Domaining phase, the DC Output was domained in ‘bagless’ separation technologies i.e., the domain of causal matches in which airflow pressure causally engages, in the middle of the causal process, with bagless separation entities. This was crucially different from the traditional technological domain of bag separation technologies, in which airflow pressure causally engages, in the middle of the causal process, with a bag. Indeed, it was precisely this domaining that set Dyson apart from the rest of the world.
- At the Matching phase, the DC Output was matched with the DC Input of a miniature cyclone unit (i.e., a centrifugal separator which separates dirt out of the airflow, instead of using the cloth of a bag to do the separation).
- At the Essentialisation phase, an arrangement of essential physical conditions was stipulated, and included a motor driven fan etc. plus the all-important ‘dual-cyclone’ (i.e., two cyclone units in a series, the upstream is parallel-walled for separating large debris, and the downstream is frusto-conic for separating fine dust). It was this essentialisation that confirmed that the DC Input – DC Output match actually works.
- At the Accessorisation phase, the numerous added accessory physical conditions included industrial design features such as positioning the frusto-conic cyclone inside the parallel-walled cyclone, and the innovative use of materials and colours, which were included in the first product: the ‘Cyclone.’

4 THE WORKSHOP

The workshop took place online in April 2021. It was attended by nine engineering doctoral researchers and lasted for three hours. The objectives were to provide a basic command over two tools:

- **Half-Causation Branching:** How to logically map a given inventing space, systematically pinpointing multiple inventive concepts.
- **Half-Causation Encapsulation:** How to optimise the scope of sought patent protection.

The workshop started with a lecture introducing Half-Causation, including questions & answers. The participants' questions indicated that they were engaging with the philosophical content, specifically asking about the nature of *Half-Causation as a method*; the distinction between a *Distinctive Causal Input* ['DC Input'] and a *Distinctive Causal Output* ['DC Output']; and the distinction between *Essential Physical Conditions* and *Accessory Physical Conditions*. Following that, the exercise part started. The participants were given a design problem that relates to increasing the safety of bicycles. They were asked to logically map the inventing space using Half-Causation Branching, searching for solutions. Here is the problem:

How to decrease the probability of a cyclist unseating (flying over the handlebar) when braking at high speed?

Due to the limitation of time during the workshop and to assist the participants get going, they were given a part-completed Half-Causation Branching template (which is not shared in this paper). The completed part can be summarised as follows. The first task was to conclude the Half-Causation phase, by making a clear statement of the Half-Causation logical branch. So, in the proper Half-Causation terminology (and more importantly its 'conceptual framework') the problem which was originally stated as a *question* needed to be converted into a statement of the *desired **DC Output***. This statement reads: **Decreas*ed* probability of a cyclist unseating (flying over the handlebar) when braking at high speed**. Such a clear statement defines the 'boundaries of relevance' of *this* problem/project. So, the participants were instructed to avoid ideas such as 'cycling slowly in the first place,' or 'taking the bus instead of cycling altogether'. Such ideas, as valuable as they may very well be, are irrelevant to the stated problem (which specifies the use of a bicycle, and cycling at speed), and as such the reasoning should exclusively focus on relevant information.

Following that, it was presented to them that instead of paying attention to 'morphological' and 'functional' considerations, Half-Causation focuses on *causal properties* (of the DC Output, or the DC Input, whichever the first phase consists of), each of which defines a given domain. So, three causal properties of the bicycle DC Output were pre-identified, and as such the participants were presented with *three domains*, namely: **speed**; **cyclist's body** and **handlebar pivot**. The participants' task was then to search within each domain for multiple DC Inputs, each of which can be matched with the desired DC Output to form an inventive concept. The three pre-identified domains were not intended as being exhaustive. Indeed, participants in other workshops occasionally identified other domains, and so did some of the participants in this workshop. However, the purpose of the exercise is not to exhaustively map the inventing space and actually develop an invention, but to train the participants in systematic reasoning using Half-Causation Branching. Due to limitation of space, this will not be addressed further here.

4.1 Exercise Outcomes

Circa 15 minutes were spent presenting the problem to the participants. Following that, the participants were divided into 4 teams each in a Microsoft Teams breakout room and given one hour to see how far they can progress their reasoning. Each pinpointed DC Input would be matched with the desired DC Output to constitute an 'inventive concept.'

Team 1 consisted of three participants. They managed to pinpoint 11 DC Inputs.

Team 2 consisted of two participants. Their grasp of the problem situation and the use of Half-Causation Branching was impressive. In the branching template they were given, they managed to pinpoint 13 DC Inputs. As they ran out of space, they created their own Word document and listed 5 more DC Inputs i.e., 18 DC Inputs in total.

Team 3 consisted of two participants. They managed to pinpoint 7 DC Inputs.

Team 4 consisted of two participants. They managed to pinpoint 8 DC Inputs.

The following is a summary of the matched DC Inputs which were generated, quite a few of them were pinpointed by more than one team, albeit occasionally with a different terminology.

- Within the domain of speed, the matches included: ABS technology, wind shield, parachute, folding flaps, smart helmet, alarm system, and augmented reality (google glasses).

- Within the domain of cyclist's body, the matches included: strap up (seat belt), drag flap (on the body), airbag, bent frame as to make the CG more towards the back wheel, reverse brake in seat post (to automatically lower the CG), and magnetic clothing & seat.
- Within the domain of handlebar pivot, the matches included: (permanently) raised handlebar, automatically raised handlebar when braking, suspension damping (axial springs/pneumatic/hydraulic).

4.2 Half-Causation Encapsulation

The workshop then moved on to how to optimise the sought patent protection, using Half-Causation Encapsulation. Only 30 minutes were available. First, the participants were provided with basic information about patents, largely based on Abolkheir 2021 [2]. So, a patent protects the way an invention works, as opposed to a registered design which protects how a product looks. A patent is a monopoly which prohibits others from practicing the invention, in a given country during the validity of the patent. A patent application consists of several parts: Abstract, Description and Claims, which may be supplemented by Drawings. The Claims are the most important part, as they state the legal boundaries of the invention. Whilst mathematics can be used in the Description, and whilst the Drawings can be referred to in the Claims, neither can be included in the Claims. What does this mean? It means that ultimately a patent's enforceable legal boundaries boil down to the use of *language*. Indeed, it is language , language, language! A crucially important lesson for engineers and designers to learn if they desire to obtain patents. Of course, patent agents write the patent application, and they work with the inventor(s) to clarify the nature of the invention. However, it is not their role to contribute to the inventing process as to become co-inventors. That is why inventors would benefit from learning how to formulate and state their inventions in a *clear, optimised language*. This is where the tools of Half-Causation Branching, and Half-Causation Encapsulation come in. The basic idea is to first identify, then plug, any gaps in the sought patent protection, through which infringers can circumvent the patent. So, first Half-Causation Branching assists with pinpointing *multiple* inventive concepts, then Half-Causation Encapsulation assists with encapsulating them within a *Single* Inventive Concept. This satisfies the legal requirement of having 'unity of invention', and protects a broad class of technological possibilities, including some which may be developed in the 20-year life span of the patent.

The participants were then presented with a pre-prepared pedagogic example from previous workshops, which related to the same bicycle design problem, and resulted in three inventive concepts, within the domain of cyclist's body, namely: *bucket seat*, *angled seat*, and *spring-loaded seat*. So, if you invented one, a competitor could invent one of the others and circumvent your patent. Now, can they all (and more) be encapsulated in *one* patent application? Here are the four Half-Causation questions, which inventors (and their patent agents) need to answer:

1. What is the invention's Distinctive Causal Output? I.e., what the invention purports to achieve.
2. What is the invention's Distinctive Causal Input? I.e., what is unique about the invention.
3. What are the invention's Essential Physical Conditions? I.e., the absolute minimum features without which it cannot work, which should be included in Claim 1 (and any other independent claims).
4. What are the invention's Accessory Physical Conditions? I.e., variations which should be introduced alternately and in combinations in dependent claims.

- The answer to the first question is simple: *decreased probability of a cyclist unseating (flying over the handlebar) when braking at high speed*.
- The answer to the second question requires 'higher order terminology' which encapsulates all three inventive concepts (and more). Here is a basic example. If a term like 'slotted head screw' is used in a claim, a competitor can use a 'Phillips head screw' to circumvent the claim. However, the term 'screw' is higher order, and the term 'mechanical fixing means' is even higher, and thus better. So, an encapsulating higher order term for the DC Input in the bicycle is: '*unseating-resistant means*.
- The answer to the third question is: *attachment means* (to attach the system to the bicycle frame), and *cyclist supporting surface*. These are the absolute minimum features.
- The answer to the fourth question consists of a long list of variant features, which are stated using lower order terminologies that are introduced in subsequent dependent claims.

Ironically, the three inventions we started with become downgraded to being mere variations (Accessory Physical Conditions)! So, the bucket seat, the angled seat, the spring-loaded seat, and others are introduced as variations of the DC Input of *unseating-resistant means*. The Description (preferably accompanied by Drawings) should include sufficient technical details which enable a person skilled in the art to practice the invention and support the Claims.

5 CONCLUSIONS

Half-Causation has been successfully presented and implemented in a workshop with doctoral engineering students. From methodologically qualitative observations at the workshop (and other workshops), the teaching of the Half-Causation tools needs to be given appropriate time to allow each student to get a firm grip on it and master its use. Unlike a brainstorming session, there is little value in rushing the process. Notwithstanding scheduling pressures, it would be beneficial for the students that the delivery is for longer than three hours, split over two days. For example, an undergraduate engineering student used Half-Causation to co-invent a system, which has since been granted a GB Patent [8]. After attending a 3-hour Half-Causation workshop, he attended three weekly 2-hour one-to-one mentoring sessions with Mo Abolkheir. So, besides the *nine* hours of contact, the student benefited from three weeks of in-between time to think and research. In any event, the systematic ordering of Half-Causation was put into practice almost immediately during the workshop. Whilst idea generation techniques and taught design processes exist for solving technological problems, Half-Causation is distinguished by the 'Domaining' which is interposed between the problem and multiple potential solutions. Furthermore, Half-Causation is unique in that it uses the same philosophical framework for solving technological problems and for exploiting technological opportunities; this is an area of Engineering Design pedagogy that is worth further exploring. Strategically, Half-Causation benefits from targeting patentability. It is therefore recommended to add the Half-Causation tools to engineering curricula, both in terms of idea generation, and intellectual property protection, specifically patents.

REFERENCES

[1] Abolkheir M. If You Wish to Invent Then Follow the Half-Causation Method. *Techné: Research in Philosophy and Technology, 2019, Volume 23, Issue 1, pp 26-50.*

[2] Abolkheir M. How Half-Causation can enlighten the drafting of patent claims. *Queen Mary Journal of Intellectual Property, 2021, Vol 11, No 4, pp 469-483.*

[3] Popper K. *The Logic of Scientific Discovery*. 1959 (Routledge), pp 31-32.

[4] Pahl G., Beitz W., Feldhasen J. and Grote K. *Engineering Design: A Systematic Approach*. 2007. (Springer), pp 85-86.

[5] Dieter G. E. and Schmidt L. C. *Engineering design*. 2012 (McGraw-Hill), pp 214-241.

[6] Dyson J. *Against The Odds: An Autobiography*. 2001 (Texere), pp 98-129.

[7] Patent No. EP 18197. [Accessed from www.epo.org 3 March 2022].

[8] Patent No. GB 2588495. [Accessed from www.epo.org 3 March 2022].