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Proposing LEAN in the Development of Smart Energy Vision 2030 Compliant Education

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ABSTRACT: The positive adoption of renewable energy technology is paving the way to improve the way electricity is generated, transported and distributed to customers. This gives rise to integrated energy systems with diverse energy sources. Today a plethora of ethernet technology, wireless sensors, and actuators are some of the key elements embedded in the energy system.It became easier these days to manage, control and optimize the integrated energy system. The use of digital technology in an electrical network, called "Smart energy" have grown in strides in recent years. This continue to have an important impact on how society will be doing business, govern, educate, and lastly affect human behaviour, which have been turned upside down by the Covid 19 pandemic. Universities find themselves under increasing pressure to update their curriculum, to better prepare students for a modernized energy and power industry, with multimodal content delivery. The incorporation of smart energy technology into the curriculum, based on LEAN approaches in delivery and management, presents a set of unique challenges. LEAN can inculcate a student that is more self reliant and with sustainability ingrained by the educational shift in approach at University level.

KEYWORDS: Smart energy infrastructure , Energy Efficiency, LEAN Development, Academic Capacity Building.

I.INTRODUCTION

The following definition of Lean Engineering Education is presented by Carvalho Alves A et al [1] as:
"A systematic, student-centered and value-enhanced approach to educational service delivery that enables students to holistically meet, lead and shape industrial, individual and societal needs by integrating comprehension, appreciation and application of tools and concepts of engineering fundamentals and professional practice through principles based on respect for people and the environment and the rigorous use of continuous improvement."

Lean Learning is that Learning & Development (L&D) process of getting the proper learning, to the proper audience, at the proper time, within the right quantity to realize perfect work flow, while minimizing waste and being flexible to improvements or variation in content. This discipline focuses on Learning and Development efficiency (the so called learning inputs-to-outputs ratio). Against the energy development plan and the associated education challenges to meet this demand, we will investigate the uptake of Lean Learning in new programmes of the sector. Planning is however of little value unless the process is positioned from the perspectives of educational stakeholders. The stakeholders in this case are the newly graduated engineers, industry, faculty at Universities and the elements of society impacted by the work product of Energy engineers.

The National Energy Plan of the Department of Energy forecasts the large-scale penetration of renewable energy sources, mainly wind and solar PV [11]. The plan makes the increased uptake of distributed energy generation possible. The successful transformation of the power industry in South Africa will of necessity involve the steady transition towards the smart energy infrastructure. South Africa's power industry is currently suffering from ageing infrastructure, small reserve margins and has by far the largest carbon footprint on the continent.
The workforce in the field of power engineering is becoming smaller in comparison to the increasing demand and the continuation of the existing power systems experience needs to be kept in order to meaningfully move into the new era of power technology [2].

In assessing the developments in smart energy and associated engineering education we can identify a number of the areas of experience required [3, 5]. A curriculum programme should include specialist courses on advanced topics associated with smart energy on graduate level and also as an exploration project which will target specific challenges experienced by the evolving power systems industry. The challenge would be to design a course that provides students

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with the necessary background knowledge to enable them to support the developing smart energy infrastructure in practice. It is foreseen that the 4IR enabled industry will require specialists in the field of power electronics and industrial automation, as deployment of smart energy will be highly automated.

There is a wide selection of topics applicable to smart energy infrastructure design and a quick overview shows that the combination of the associated technologies and methods exceeds that of what is currently taught at bachelor level education. The power industry is struggling to alter the way it's been operating for much of the past century. The main drivers of change have been the rapid increase in demand for energy that is more reliable and secure, a greater focus on energy efficiency, a rise in distributed energy generation and a global demand for cleaner energy through a major shift towards renewables. This has been accompanied by a much greater emphasis on active engagement of the consumer in various processes related to energy supply and demand.

Responding to these pressures presents a range of challenges for this sector of industry, which in many instances is also beset by ageing infrastructure, overburdened grid capacity and outdated technology. [4] Smart energy is often put forward as the means of addressing these challenges.A useful definition of a smart energy system must encompass its ultimate applications, uses, and benefits to society at large. This must include variety of key features and characteristics including, but not limited, to the following:

It must facilitate the combination of diverse supply-side resources including increasing levels of intermittent and non-dispatchable renewable resources;
It must facilitate and support the combination of distributed and on-site generation on the customer side of the meter;
It must allow and promote more active engagement of demand-side resources and participation of customer load within the operations of the grid and electricity market operators;
It must allow and facilitate the prices-to-devices revolution that consists of allowing widespread permeation of dynamic pricing to beyond-the-meter applications. [6]

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II.THE EDUCATION CHALLENGE IN ENERGY

Mills & Treagust [8]exposed the following concerns concerning Engineering Education :
• Programs are content driven with the result that engineering curricula are debatable when focused on engineering science and technical courses without providing sufficient integration of these topics or relating them to industrial practice.This point can be particularly difficult to implement in evolving technologies like smart systems, AI, and electric transportation.
• Current programs do not provide sufficient design experiences to students.
• Graduates still lack communication skills and teamwork experience and programs need to incorporate more opportunities for students to develop these and other competencies.
• Programs need to develop more awareness amongst students ofthe social, environmental, economic and legal issues that are part of the reality of modern engineering practice.

As a consequence, universities find themselves under increasing pressure to update their curricula , and in this case the power systems curriculum, to better prepare students for a modernized power industry that is steadily incorporating more smart energy technology. Typically, the traditional power systems curriculum would cover the fundamentals of power generation, transmission and distribution, which would include power systems modelling, protection and control. With the advent of smart energy, and by extension a subsystem like the smart grid, such a curriculum would now have to include information systems, network communications, power systems automation and protection.[5] The large-scale integration of renewable energy resources and the challenges this presents, along with the application of power electronics and energy storage technologies which are fluid and changing to address these challenges will necessarily have to be covered as well.[7]

While it will be necessary to revise the undergraduate curriculum and make it more relevant by including topics related to smart energy technology, the danger of an overcrowded curriculum needs to be acknowledged. Care must be taken not to broaden the curriculum at the expense of depth, thereby compromising on the fundamental knowledge required by engineers. This is of particular concern at a time when demands are being made for the inclusion of a number of other topics in the undergraduate curriculum This must be done in such a way , so that it does not impact negatively on laboratory work [9].

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The introduction of smart energy in a modernized power industry will however require the support of a multidisciplinary approach to training and education with a much broader skill set than is currently the case. The modern power system with embedded generation, microgrids and inclusion of the smart grid will rely heavily on communication and data acquisition technologies for its effective operation. It will involve increased automation and real-time control at all levels and will necessarily incorporate advanced power electronics and digital technologies to ensure system safety, reliability and efficiency. The modern power systems engineer will be required to integrate knowledge from all these different fields. [18]

III.LEAN ENGINEERING EDUCATION BENEFITS AND IMPLEMENTATION STRATEGIES

Lean Engineering Education is based on the 4P's of lean culture and practice, namely Philosophy, Processes, People and Problem Solving. [19] This should produce the correct combination of content and competency development. In fact, Lean Engineering Education requires collaborative problem identification/solutions and high levels of vertical, lateral, internal and external communication. Add to that a highly-developed technical expertise and the engagement philosophy of the head, heart and hands of an engineering student in pursuit of their education.. When engineering degree program design relies on Lean Engineering Education, the possibilities for attaining both content and competency mastery can increase greatly. These possibilities in Lean are greater than they are in traditional content-based program development. Instead of introducing additional coursework to meet workplace requirements,it is possible to both integrate and spiral competency development with the content of engineering subjects by pedagogical alignment with thelearning systems embedded in Lean.

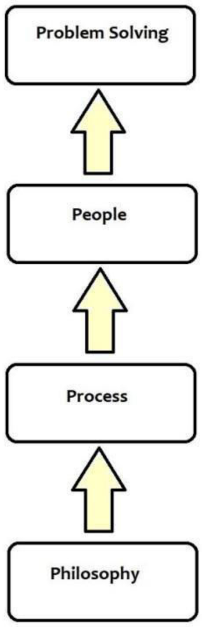

Figure 1: 4P's adapted from Liker [19]

In this approach, Liker (Figure 1)introduces the Japanese motor corporation's educational system around the principles of educational philosophy , process, people and problem solving [19]. Philosophy is the long term view and goal. Process, in contrast to traditional systems, is not about more paper work and more routines, but instead about waste elimination and streamlining. People are all about respect, partnership ad growing trust. Problem solving is about the embracing of continuous improvement and learning as part of how to be.

Applying the problem-solving tools presented early and normally usedin an industrial environment, the students will develop thinking capability because they learn to think in systematized and inductive way. In this way a student with systems competency or mastery will arise. Students would also learn to search for the root cause of problems through deductive thinking instead of trying to solve symptoms.[12][13]. The approach to Lean learningis predicatedon those

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of lean manufacturing and lean software development. Teaching and Learning departmentsthat mightwant to transition to lean learning mustinculcatethese three dimensions shown in Figure 2.

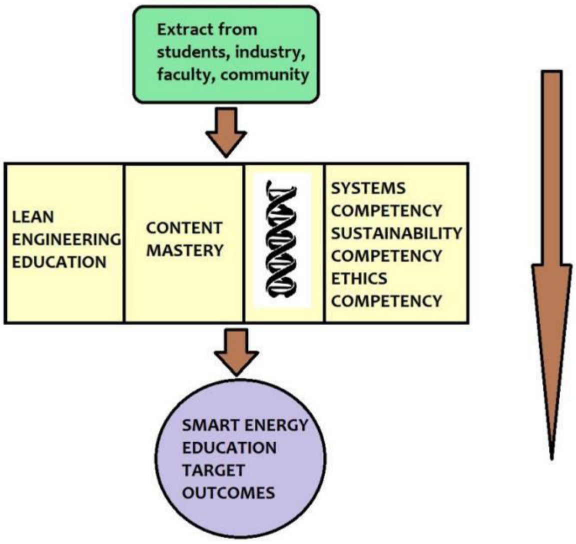

Figure 2: LEAN double helix Content and Competency Mastery adapted from [22]

Lean Education managers must remove as far as possible “overburden” on their stakeholders—learners, and lecturers. All the unreasonable activities imposed on learners and systems as a consequence of poor organization—such as cumbersome training equipment, travelling to classroom locations, and dangerous tasks must be first eliminated. Overburden pushes learners or systems beyond their natural limits[13]. The management may simply be requesting a greater level of performance from a process than it can handle without taking short-cuts and informally modifying decision criteria. Unreasonable work is almost always a reason behind multiple variations and lowering quality, not enhancing it. During and in the aftermath of the Covid 19 pandemic, education had to continue regardless, and one can say that the methodology of multi modal teaching and learning is the precursor to Lean being adopted in the education sector. Alves [12] conclude that Engineering students are the future professionals of the companies and their teaching and learning must be aligned with industry and society needs. Students in this process will develop competencies and will also develop the ability to evaluate and meet the demands of a high degree of complexity, which is all coming in the post 2030 world.

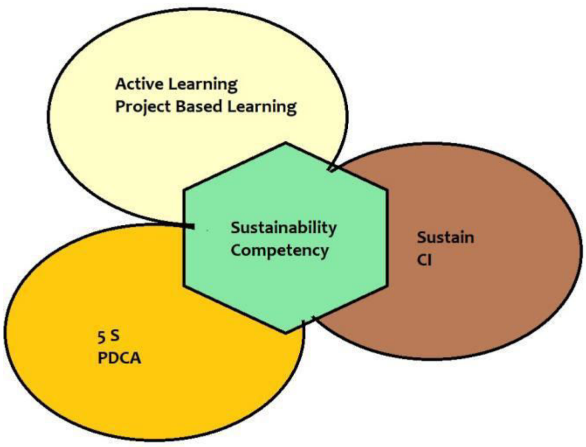

Figure 3: LEAN sustainability competency

The pursuit of perfection is a lean principle that engages the tools and thinking of continuous improvement to create value by eliminating wastes, as depicted in Figure 3. Feeding into sustainability competency is the Lean Tools of PlanDo-Check-Act (PDCA) and the 5S, a sustainability tool used to improve basic problem metrics, such as cost,

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quality, safety, delivery and morale. This leads to the process of Continuous Improvement (CI), which can be considered as an organizational process of sustained and focused incremental innovation.

Lean specifies nine deadly wastes as overproduction, transports, inventory, motions, waiting, over-processing, defects, knowledge and energy loss. These wastes are clearly related to sustainability competency. For example, consider environmental waste, as defined by the US-EPA [14] as an unnecessary use of resources or a substance that is introduced to the water, land or atmosphere that could pose harm to human health , the habitat or the environment. Environmental wastes can occur when companies use resources to provide products or services to customers, and/or when customers use and dispose of products. Lean attacks these problems evident in environmental waste and advocates for "doing more with less" and "creating more with less," not by working harder with fewer resources but by expanding value through improvement. [15] In other words, as an expression of sustainability competency mastery, the Lean Engineering Education student develops an in depth understanding of the symbiotic relation of production and the environment [16]. Lean Engineering Education in the smart energy sector will develop a Lean seeker of wastes in all forms, as a demonstration of sustainability competency development. Streamlining becomes essential and educators must strive to eliminate "unevenness" from Lean programme deliveries. Here one can draw a parallel to another Japanese influence. The smoothness-based approach, also known as the flow-based approach, which objective is to achieve just-in-time (JIT) operations, act by removing the variation commonly caused byscheduling. This encapsulate a rationale, driver or target as well as clear priorities for application in practice, using a variety of techniques. This is well experienced by educators forced to use multi-modal content development and delivery due to the Covid 19 pandemic. To achieve JIT requires effort and it exposes many quality problems that are covered in traditional systems by buffer programs. In order to be fluid the implementation only value-adding steps creates smooth flow. Given the demands on the traditional four-year undergraduate engineering curriculum, there may be little room in the undergraduate electrical engineering programme to cover the fundamentals of the power systems field and also to include additional modules to adequately prepare the student for the modernized power industry incorporating smart energy technology. But with the Lean programme development and smoothness achievable by JIT, this will become much more achievable.

Dragomir suggests that the common driver for implementing Lean is a time of crisis or an event that change the normal order of things. In case-studies evaluated by Dragomir and Surugiu, one such crisis moment started with a budget reduction. In this case the adoption of Lean was as reactive response. One should however be cognisant that people often naturally resistant change and thus the adoption of Lean in a new situation must be done with great care. Heads of Departments and Faculty must have upfront buy in and should be made to understand the benefits of Lean implementation and the steps of the implementationprocess. Since Lean is a long-term customer oriented initiative of improvement, and improvement ways must be found continuously [20]

Ethics development will cultivate in engineers an outcome known as corporate social responsibility. This competency is one that serves as the foundation of Lean Engineering Education, a support to the Systems and Sustainability competencies. When Lean Engineering Educationteaches the ethics competency, it is possible to develop a conscientiousattitude and behaviour of perfection based on goodwill and moral foundations of civil society. Outcomes, such as enabling enriched thinking, mature attitudes, and sophisticated approaches to better resource efficiency and productivity or doing more with less, because it is the right thing to do, is expected and fostered.

Ethics pulled by Lean Engineering Education opens up options for deeper levels of critical thinking and analyses, well-conceived mitigation of risk and consequence, engaging difficult conversations of both advocacy and inquiry, and internalizing incentives to not only do well, but to do good as work product. Lean Engineering Education seeks to develop champions of ethical competency by modelling, teaching and rewarding corporate social responsibility.

The impact of Lean Engineering Education could be substantial. If energy engineers could interact with the world to overcome failureto conceptualize systemic consequences, to withhold consumption of resources beyond the earth's means and to engage in good for the advancement of civil society, then planning for the future of energyengineering education is time well spent. While on the one handit'llbe necessary for power systems engineers to integrate knowledge from auxiliary fieldsso asto support the effective operation of the smart energy infrastructure, the industry also requires specialists in auxiliary fieldslikeInformation Technology and Communications Networksto usetheir expertisewithin thearea of smart energy infrastructure. smart energy infrastructure systems are expectedto supplyhuge amountsof informationthrough monitoring energy usage throughout the day inscores ofhouseholds. Information Systems specialistsare going to berequired toaffectthe challenge of processing all this data and presentingthe datain a

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verymeaningfulmanner toenable consumers to participate in energy delivery andto helpsystems operators in optimizingsmart energysystem. smart energy infrastructure systems will involve numerous intelligent devices,which requirebi-directional communicationwithone anotherover a digital network.

Manythe chosendevices will come from different vendorsand therefore theinteroperabilityof thosedevices presentsa specificchallenge. Information Systems specialistsare going to berequiredto deal withthese challenges. Withthe massiveamountof informationbeing generated by smart systems,there'llalways bethe strainbetween data access and data privacy. Cybersecurity thus also becomes a challenge relevant to the smart energy infrastructure, which Information Systems specialistsare going to berequiredto handle[17]. Students with an undergraduate degreein the field ofInformation Systems and Network Communications field are unlikelyto possessenergy or modern power systemengineering background.

IV.CONCLUSION

The power systems industry is under pressure to transform and modernize its operations. The range of challenges the industry currently confronts is being addressed by the incorporation of smart energy infrastructure technology. However, the smart energy systems involves the integration of a number of disciplines, and there is a severe shortage of skilled personnel with the necessary expertise across these disciplines to support the effective implementation of smart energy.

The future energy engineer will definitely be involved in companies in development or service sectors which all involve processes that are linked together in a particular fashion, sequence or design. The energy engineer needs to see that all these processes that use man, machine, materials, methods, information, energy, utilities and consumables as inputs or factors of service or production in turn, they all are worked on to create the final output of the system. The upcoming energyengineer needs to understand that these element exist in a complex configuration as all of these parts must work together to achieve a common goal to produce the output according to the level of quality and quantity required by the end client or customer. And further that all work is done in a way that produces benefits for the common good of civil society.

The input of LEAN Engineering Education would be significant in the designing of the processes and products of a power system. The engineer needs to understand that a starting point is consumer viewpoint and the ability to create value into the design. Waste elimination and energy efficiency is not a luxury but an essential component of all energy systems within the 2030 vision. The lessons from LEAN, and the philosophy from LEAN can be a key driver in the development of competent energy engineers within that vision.
Universities have an important role to play in the development of curricula to prepare students for the modernized power systems industry. This paper argues that adoptingLean Engineering Education will be most appropriate to integrate the various disciplines applicable to the smart energy sector..

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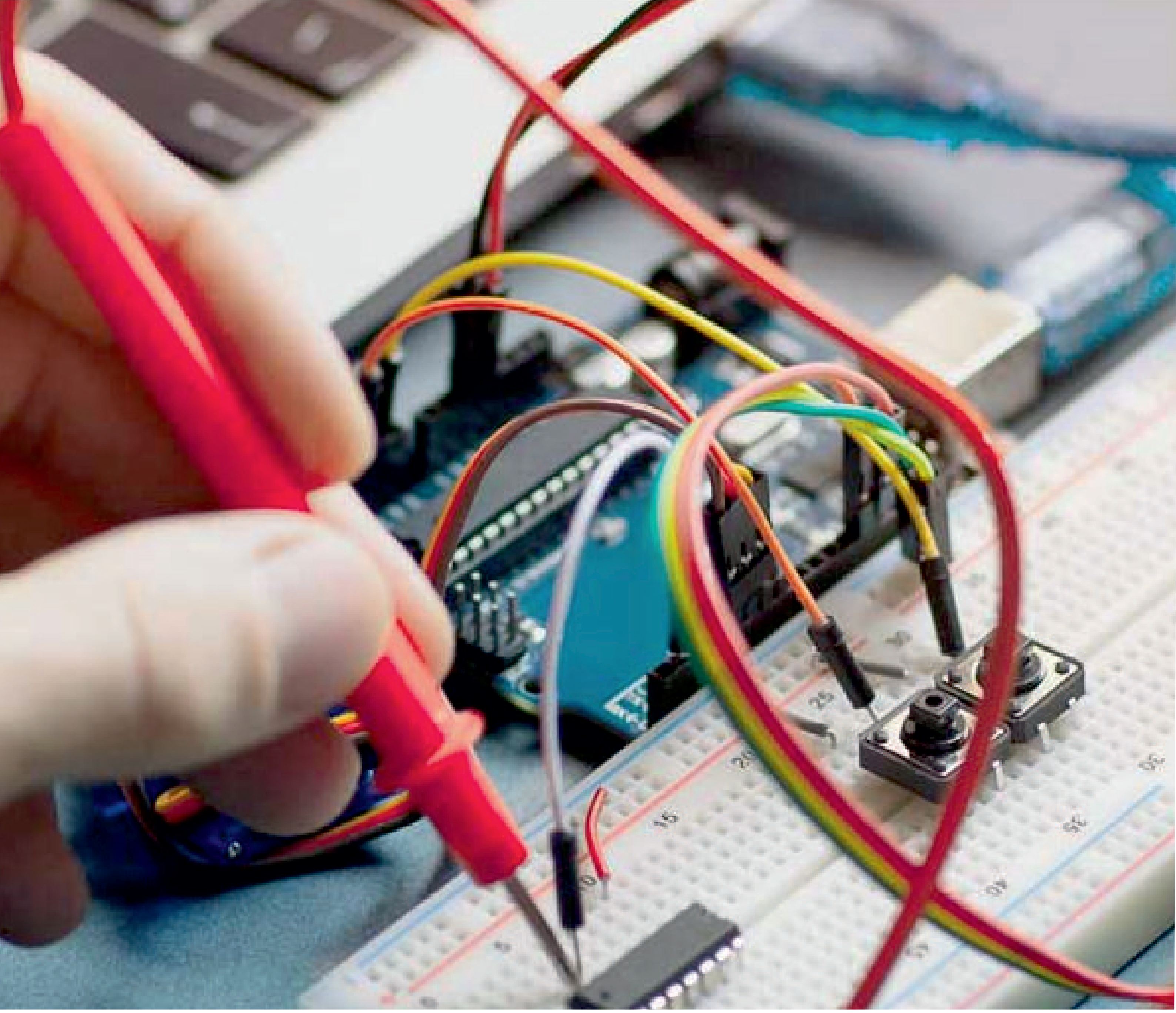

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