Teaching Power Electronics as a Multidisciplinary Subject with Small and Inexpensive Robotic Arm

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Abstract. Experience shows that teaching Power Electronics subjects is not easy, even to undergraduate students. This phenomenon might stem from the fact that Power Electronics is an engineering discipline that closely related to other disciplines. Some experts stipulate that Power Electronics is a multidisciplinary subject while for some other it is an interdisciplinary subject. In students point of view, it does not matter what side Power Electronics reside, they always see it as a difficult subject. Most of the time engineering technology (TVET) student might consider this subject more as a burden. This does not come as a surprise; sampled Indonesian students score lower in PISA (Programme for International Student Assessment), a periodic student testing conducted by OECD (Economic Co-operation and Development). The score outline the lack of HOTS (Higher Order Thinking Skills) from many Indonesian students. The inadequacy in that skill hampers the future development of many students, especially in a subject such as Power Electronics that require some degree of mathematical prowess and deeper thinking. It gets worse with the influence of technology on student attention span, and they cannot focus on a more extended period as their predecessor was. This kind of deficiency threat the very survival of the nation as we enter The Industrial Revolution 4.0 where many current human jobs will be replaced by network connected automation. We need to address this problem adequately. The massive national interest in robotics may be one of the answers to this problem. However, due to the expensiveness of this solution, it needs to be adapted to the available budget. The literature study that used as a foundation of ongoing effort to incorporate a simple robotic experiment in Power Electronics teaching is presented. The study then followed by a discussion about the current state of the effort.

Keywords: ADDIE, CDIO, robotic arm, Arduino, vocational, engineering education, education technology

1. Introduction

1.1 Philosophy
What is philosophy? It is not easy to precisely define what philosophy is. But in this paper (for practical purposes) we can look back to its inception times. The term ‘philosophy’ comes from the Greek – it means ‘love of wisdom’. Philosophy teaches the habit of asking about the world around us and ourselves. Philosophy also teaches us not to be easily trapped by the pitfall of the artificial boundary of any scientific branches. In Pritchard words, “the idea of philosophy as a completely
distinct branch of knowledge-seeking is not something that would be recognizable to many of the most famous philosophers in history, and certainly not the ancient philosophers who invented the term [1].

In general, basic understanding about philosophy as the basis of science is essential so that one can develop knowledge, better understand the world, and not be trapped in any narrow sectoral interests. It is also essential as a tool to be able to solve problems in engineering education that requires more than one branch of science.

1.2 What is science
Defining science is as tricky as defining philosophy. Many perspectives on the definition of science have been put forward [1]–[10]. Discussing science at a great length is not the purpose of this paper, but a simple understanding of the term science is needed. Science in its purest form is the effort to ascertain the truth about a particular subject matter [1], it is the quest for truth [3]. The term “science” is of Latin origin, where the word “scientia” meant knowledge. Thus science involves activities such as acquiring and preserving knowledge [7]. Science is an accumulation of knowledge [8], science (in turns) also generates knowledge [6]. To do its function, science depends heavily on systematic thinking. Science teaches the value of rational thought, as well as the importance of freedom of thought [10].

Modern engineering and technology are firmly based on science. To understand the subjects, one must grasp a basic understanding about science (what is considered as scientific) and also things that are treated as pseudoscience [4][9]. There is a widespread misunderstanding that vocational learning and teaching can shun or even ignore science. It narrowly focused on psychomotor development. This is not only wrong but also dangerous, especially when the world enters the Industrial Revolution 4.0. Engineering and technology are derivatives of science and in turn from philosophy. All three of them, science, engineering, and technology are interrelated and advance each other.

1.3 Why hard science is hard
In present-day, the boundaries between soft science and hard science are no longer so obvious. However, it is important to understand why this grouping occurs and how it works. In shorter version [2], according to the Biglan classification scheme, fields in which a paradigm consensus exists are considered “hard” and fields without a paradigm consensus are considered “soft.” A similar sentiment is highlighted in [5] that social science is found lacking in methodological rigor. In their work Andres and Dobrovska recount that conventional engineering curriculum is strongly based on the development of technical knowledge and skills. It encourages logical, rational, analytical, pattern seeking, solution-solving, sorting and organizing. It mostly focuses on teaching and training hard facts which are relatively easy to be taught and tested [11]. This practices can be seen as a continuation of hard science tradition.

Notwithstanding that hard science education and mathematics alone are considered insufficient for the education of an engineer in this era [11]. Engineering requires attributes of the humanities found in social sciences (soft sciences): creativity, artistry, intuition, symbology, and emotions [12]. Traditionally, physics is classified as a part of hard sciences. Although it is said that as hard science physics should be easier to teach compared to soft science, in reality, this subject is considered to be more difficult [13]. Maybe because questions and problems in this subject are mostly closed-ended. Wrong answers and incorrect solutions can be found out faster and easier. Most students find it discouraging as they do not have more free room to follow their own wishes and imagination.

1.4 Power electronics
As observed by Batarseh, up until now, no single widely accepted statement defines the field of power electronics, primarily because of its application oriented and multidisciplinary nature that encompasses many subareas in electrical engineering [14]. The similar observation is also reached by others as in [12]. Bai in [15], assert that power electronics is a branch of engineering that combines the generation, transformation, and distribution of electrical energy through electronic means. This assertion is similar to Newell that in 1974 described power electronics as a combination of electrical engineering, electronics, and control theory, which has been widely accepted today [16].
In today’s world power electronics encompasses more than what it was in 1974. Trzynadlowski estimate that at least half of the electric power generated in the USA flows through power electronic converters, and an increase of this share to close to 100% in the next few decades is expected [16]. Due to its history, there has been some misconception about power electronics. It was thought that power electronics only dealt with high power and high voltage applications. However it is not the case, power electronics includes applications in which circuits process milliwatts or megawatts [20]. In this regard, the estimation that almost all of the electric power generated in the near decades will be processed through a power electronics module is much more plausible.

A case of multidisciplinary: Power electronics is a multidisciplinary subject. Therefore a power electronics course should be multidisciplinary and involve semiconductor physics, digital signal processing, controls, circuits, computers, mechanical design, thermal and electromagnetic phenomena, and other disciplines [15][17]. Batasareh in [14], states that because of this multidisciplinary nature of the field of power electronics, experts must have commanding knowledge in several electrical engineering fields such as electronic devices, electronic circuits, signal processing, magnetism, electrical machines, control, and power.

1.5 Teaching challenges
Teaching power electronics has always been a challenge. It heavily based on physics and involving much mathematics. It is because power electronics is an engineering branch. Therefore, as we treat philosophy and science, we first should clarify the term. Engineering usually refers to the creative application of scientific principles used to plan, build, direct, guide, manage or work on systems to maintain and improve our daily lives. Engineers aim at practical ends; engineers also seek to create things that are not found in nature. In contrast to engineers, scientists seek cognitive knowledge; they seek to understand the given universe and its various components. This is because science generally refers to knowledge based on observed facts and tested truths, which are arranged in an orderly system, which can be validated and communicated to other people [17].

In a discussion about engineering, the term “technology” will often be encountered. Anthonie Meijers shows that both the term “technology” and the term “engineering” originate from words that indicate a practice-oriented type of knowledge [18][19]. Still, according to Meijers, the English word ‘engineering’ originates from the Latin ingenera, meaning to implant, generate or produce. While the English word ‘technology’ comes from the Greek τεχνη, which is usually translated as art, craft or skill. Meijers argues that technology and engineering cannot be identified exclusively in terms of a body of systematic knowledge. After all, they do not aim at knowledge for its own sake, but rather at the development and use of knowledge for practical purposes. Technology or engineering is primarily a practice which is knowledge-based [20][23]. In his work, de Vries argues that technology is the human activity that transforms the natural environment to make it fit better with human needs, thereby using various kinds of information and knowledge, and various kinds of natural (materials, energy) and cultural resources (money, social relationships, etc.). Whilst engineering is when professionals called ‘engineers’ do the human activity described before [18].

Modern technology artifact such as a smartphone is not a rarity for many students. It served as a double edge sword. While it can enhance students learning, it also takes a significant toll in terms of student attentiveness. Many students cannot uphold an attention span required to effectively study an engineering subject. Games that often can be found in the student’s smartphone gives much more pleasure than the learning process demanded by most engineering subject. The term gamification hence is the response to cope to this sort of problem [25]. Other means may be developed to have such a level of engagement of a personal computer or smartphone game for engineering subjects. Failure to have student’s perseverance in serious learning at the same level of perseverance for entertainment games may lead to fatal consequences. There are cases where engineering technology undergraduate-student flunk some subjects and eventually drop out altogether.

1.6 The rise of robotic
Starting at the end of the 1960s, robots had begun to be widely used in factories and replaced assembly-line workers [21]. More and more human work will be replaced by robots combined with intelligent technology [22][23]. Especially when the world welcomes the Industrial Revolution 4.0, where human
dependence on technology becomes so high [22][24]–[28]. News about the massive use of robots in factories and the widespread use of robots in daily life in developed countries, make the public aware of the development of robotics technology. Robotics is so popular that is no longer considered a strange thing anymore. The public began to become familiar and consider it as a symbol of the progress of times. This coupled with the existence of robotics competitions and widespread reporting about them has attracted many people interest [29].

2. Discussion and Proposed Solution

2.1 Methodology and principals involved

The primary work presented in this paper is the examination of the problems heuristically and empirically experienced by the authors. For this reason, it is necessary first to study the sources discussing the model/framework that will be used to submit a problem-solving proposal.

2.1.1 ADDIE

ADDIE is a learning framework that has been developed at Florida State University in 1957 [30][31]. ADDIE is an acronym for Analyze, Design, Develop, Implement, and Evaluate [39]. While some refer ADDIE as one model of instructional design, others refer it as a product development paradigm and not a model per se or as an umbrella term. Whatever it is referred to, ADDIE provides a constructive framework to start with. The use of ADDIE has been disclosed in several reports. For example, ADDIE is used for improving engineering students’ cognitive and affective preparedness, to develop an orientation program for graduate students, to propose a problem-based learning in engineering education at Malaysian polytechnics, and to design a model of interactive learning resources to reduce students’ cognitive load. Since our work in this study is still at an early stage, the ADDIE framework is still in the analysis phase. An analysis is conducted to identify the probable causes of a performance gap.

2.1.2 CDIO

CDIO is an acronym for Conceive-Design-Implement-Operate [32]. As an international initiative, it was launched in October 2000 as collaboration from several higher education-institution: MIT, Swedish universities of the Wallenberg Foundation, Chalmers University of Technology, Linkoping University and the Royal Institute of Technology [33].

The CDIO approach was developed in response to concerns about the conditions of engineering education [34]. The engineering education is considered emphasizing too much on the teaching of the theory of science and mathematics, so far as it is reducing the portion of real-world engineering practice training and other supporting practices such as communication skills and teamwork [32][44]. The CDIO approach aims to develop skills in problem formulation, estimation, modeling, and solution. Zhang and Liu outline that CDIO stages can be classified into three parts; learning by thinking (conceive & design), learning by doing (implement), dan learning by use (operate) [35]. According to Takemata et al., there are five stages are defined as the engineering design process: finding a problem; clarifying the problem; coming up with ideas; idea generation; develop, improve, and evaluate the prototype. The first two (finding a problem and clarifying the problem) are part of problem finding cluster, while the others are part of the problem-solving cluster. Students work in groups on project tasks, the use of problem-based learning and project-based learning are central to the CDIO approach. In this way, students will be able to apply the steps in CDIO more effectively and more efficiently.

The CDIO approach as a whole is a complex architecture consisting of syllabus and standards. Therefore, at this current stage, its full application is not part of the discussion in this research. CDIO implementation for power electronics teaching in the Department of Electrical Engineering, Samarinda State Polytechnic starts from Standard 1—The Context. In the conceive stage, the section of considering technology refers to [33][36]. The conceive stage is crucial because it is the stage where the scope of the problem is analyzed, and the specific needs are addressed [37]. This is the stages of finding and
clarifying a problem in the engineering design process [38]. The steps taken serves as a base for students to follows the CDIO process in full scale in the future.

2.2 Problems
As teaching and learning have become routine, lecturers and students (undergrad-students) alike have increasingly become a “creature of habits.” Most of the activities are carried out in a business-as-usual manner. There is no urges to stop and ask more deeply about plans, activities, output, and impact. This phenomenon worsened by the lack of appreciation of philosophical discussion (in conjunction with science, engineering, and technology). Philosophy is misunderstood as something alien in a vocational education environment. Hence, the culture of curiosity is not growing, let alone the habit of asking a serious question.

Traditionally, learning in vocational higher education emphasize more on psychomotor learning. Student’s skill is much more important than his/her cognitive development. While this might be entirely acceptable in the past decades, this scheme of learning should not continue in the era of Industrial Revolution 4.0. Just because the learning aims to practical application, it does not mean that it can ignore any scientific principles. Scientific principles, engineering, engineering science, and technology work hand-in-hand in “shaping” a student’s future.

The performance gap also comes from the fact that students shun any mathematical, science, and HOTS materials. They falsely perceive that those materials are not really relevant and not a significant contributor to their success in life. That belief seems to be firmly formed in the early ages by their surroundings and peers. To resolve issues that have been analyzed in the first step of the ADDIE model, one needs sufficient tools. One of the steps in the CDIO conceives stage is considering technology. Not all technology suitable for all scenario that is true even to the state-of-the-art technology. To select suitable technology to be proposed as a candidate to be used to solve the problems, a literature review is needed. There is a discussion about a robot in previous paragraphs that serve as an opening. Further review is needed to clarify details that are needed but still are left out.

2.3 Robotic Arm
Miller observes that in recent years, robots have penetrated the education market. It served both as tools to motivate students to explore science technology engineering and mathematics (STEM) disciplines and as concrete deployments as curriculum materials for teaching content [29]. Robotics has become an essential subject, taught in middle and high school as well as in vocational education and university. Various researchers have reported in their paper about the use of robotics in learning and teaching. Soriano et al. agreed that robotics as an experimental platform plays fundamentals role in the learning process. Robotics platform allows a visual demonstration of the basic concepts, maintaining the students’ interest and motivation. Such platform remains flexible; the difficulty can be adjusted according to the students level [39]. Gyebi et al. report that several selected African universities adopt educational robotics, following a belief that robots are an effective means to facilitate more engagement, higher motivation, and the development of practical skill sets, beyond the focus of robotics itself [40]. Souza and Duarte describe the virtue of robotics in education. Robotics develops logical thinking, raise the level of the cognitive process, provide opportunities for students to test their own cognitive models, detecting and correcting inconsistencies [41]. Martínez-Santos et al. highlight benefits offered by educational robotics; integration of different areas of knowledge, development of systematic thinking, and creation of learning environments [42].

Due to the traditional disciplinary approach, students are often failing to connect, generalize and transfer knowledge to a variety of problem-solving situations in the real world. One of the solutions for this problem is making a multidisciplinary approach to learning and teaching activities. Garduno-Aparicio suggests the approach incorporates and connects key concepts and skills from many disciplines in one activity that has students acquire and apply knowledge, skills, and strategies in multiple subject areas, and thus construct a more integrated web of knowledge. Multidisciplinary
instruction should, therefore, be a part of technical education, with the courses and projects making explicit connections both within the technical world and between engineering and society.

Unfortunately, the price of robotics platforms can be very high. Even an educational robotics kit may have a high acquisition price. Many educational institutions have limited, therefore insufficient funds [39][41][43][44]. An educational institution may not want to have a full-scale industrial robot. As Weber et al. experienced it in Germany; because of the size and the cost of a robot used in an industrial environment physical access to such a robot cannot always be provided in an academic environment. Weber et al. argue that a small articulated robot arm that has the same structure as robot arms used in industry is sufficient to be used in an educational project [45].

Robotic arms have been used in lessons in several institutions as in the following reports [39]–[41][43]–[45] Even though it is a hot research topic, the use of a robotic arm is still suitable for the learning of students from various backgrounds. Robot arms are suitable for interdisciplinary learning using multidisciplinary techniques [46]. Until recently, there is no viable option for those who would use a robotic platform in a laboratory other than using the high-priced closed-source system. However, today many options have presented and can be chosen to fit the user’s application. A multidisciplinary low-cost open platform for electronics system, control & automation, and robotics can be obtained relatively easily [39]. Arduino can be used to control servo motors for robotic arms. In general, the Arduino system can be used and integrated properly in a robotic device system.

Considering the distinctive feature of each institution, there is a need to have criteria that set as a minimum required standard to judge a technology candidate. Here is a simple list that fit into our institution feature and needs; availability, low cost, learning sources, complexity, and flexibility. Based on the literature review that has been done, the authors propose the robot arm be tested as one of a solution of the problems stated earlier. The robot arm kit can be bought from an Indonesian online merchant for under five hundred thousand rupiahs. In the future work, authors will report in more detail about the learning and teaching experiment using the robotic arm as depicted in Figure 1.

![Figure 1](image.jpg)

**Figure 1.** The robotic arm to be tested (in Power Electronics laboratory)

3. Conclusions

In this paper, an effort to get a good and strong foundation for the continuing research has been reported. The authors intend that in this early stage, the ground basis for future works needs to laid correctly. The groundwork (i.e., a literature review) has been done and reported. There is a need for engineering education to broaden the spectrum of education received by students. The transition has to be made from classical mono discipline style of teaching to modern multidisciplinary/interdisciplinary learning processes. This is a must in order to prepare students of engineering (and engineering technology) as a problem-solver in the real world, decades later. In this paper, the proper definition and connections of philosophy, science, engineering, and education have presented. A solid understanding about terms involved is a necessity to improve the learning process.
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