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Towards a flexible 2+2 hands-on engineering technology curriculum

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ABSTRACT: As a response to the rapid growth of engineering technologies and the corresponding unstable labour market demands, the knowledge, competencies and skills required from future engineers are rapidly changing. A rigid curriculum with a fixed study plan and courses is no more a sustainable solution to respond to such a rapid change, and a more flexible and adaptable curriculum that directly addresses these challenges is required. In this article, the authors present the general structure of a new flexible curriculum developed at the Australian College of Kuwait, Mishref, Kuwait, and the detailed structure of the electrical and electronics programme in particular. They examine its different flexibility degrees of freedom compared to the currently implemented fixed curriculum. Also, they discuss a quantitative estimate of the overall flexibility added by these degrees of freedom and its distribution over the general engineering knowledge, skills and discipline requirements.

INTRODUCTION

As a response for the exponential technological growth, higher education institutions are adopting new pedagogies to ensure their graduates are long-life learners who easily adapt to the increasingly dynamic nature of markets [1]. Curriculum flexibility is foreseen to address these challenges and is nowadays becoming a necessity [2][3].

Over the past years, many definitions of flexibility have emerged and were applied by higher education institutions in their curricula. This discrepancy is considered as a normal result of the socioeconomic challenges facing higher education institutions and the nature of programmes they offer (e.g. science, business, medical, engineering, etc). Some studies restricted flexibility to distance or blended learning, where students' diversity is the main motive for providing equal study opportunities and enabling flexibility in the *when* and *where* of learning [4].

Other studies presented flexibility as reinventing delivery through adopting novel learning approaches focusing on the *what* and *how* of learning [5-7]. In either scenario, curricula flexibility aims at tailoring education towards a student-centred learning approach, where the student has certain degrees of freedom to control his/her learning journey and implicitly gain lifelong learning skills [3].

As far as engineering education is concerned, hands-on skills and laboratory environments are crucial parts of the curricula and the learning process, thus flexibility is mainly introduced into engineering curricula as educational frameworks and learning strategies and techniques. For instance, conceive, design, implement and operate (CDIO) [8][9], project-based learning (PBL) [6][10], and e-learning [11-14] have emerged to address these challenges and equip engineering graduates with lifelong learning competencies and skills. Besides many others, one of the key success factors of such strategies is the student-centred model approach [15].

In this context, and in alignment with the conceptualised vision of the state of Kuwait 2035 *NEWKUWAIT* [16], the Australian College of Kuwait (ACK), Mishref, Kuwait, developed a new flexible engineering curriculum that is expected to provide graduates with the integrated knowledge, skills and experience to fulfil the needs of the local and global market, and to contribute to the socioeconomic development of Kuwait. In contrast to the common engineering programmes, the designed curriculum incorporates a 2+2-year model in which students can graduate with a Diploma degree after two years of study or pursue additional two years to graduate with both Diploma and Bachelor degrees.

In this article, the authors describe the structure of the currently implemented curriculum at ACK along with the findings of its review process. Moreover, the degrees of freedoms implemented in the new curriculum that enable more flexibility are defined. Finally, a quantitative estimate of the overall flexibility added by these degrees of freedom and its distribution over the general knowledge, skills and discipline requirements are discussed.

CURRENT CURRICULUM STRUCTURE

As illustrated in Figure 1, the School of Engineering at ACK incorporates a 2+2-year model in which students can graduate with a Diploma degree after two years of study or pursue additional two years to graduate with both Diploma and Bachelor of Technology degrees. Particularly, in the Electrical Engineering Department, a student who graduates as a Bachelor of Engineering Technologist completes a total of 145 credit hours. At first, the student completes 60 credit hours in the diploma programme and acquires a Diploma of Electrical and Electronics Engineering, then complements it with an additional 85 credit hours in the Bachelor programme to acquire a Bachelor of Engineering Technology (Electrical and Electronics).

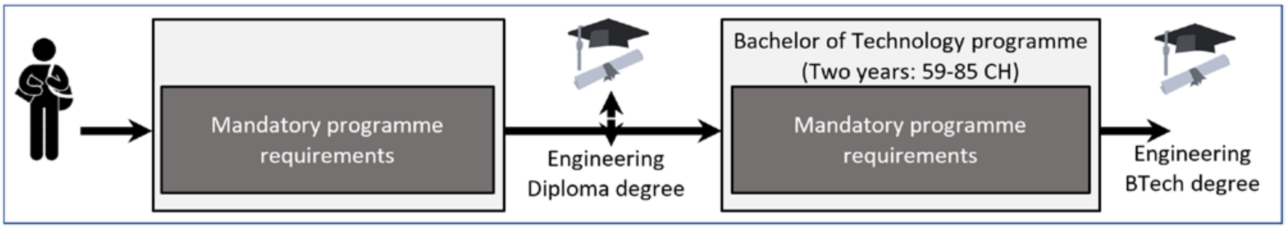

Figure 1: School of Engineering programme structure: 2+2-year model.

Both diploma and Bachelor programmes are endorsed by ACK's strategic international partners and accredited internationally by Engineers Australia and locally by the Private Universities Council in Kuwait. The latest update of the electrical engineering curriculum of these two programmes occurred in 2015 and a review was conducted at the end of the academic year 2018-2019 to evaluate its outcomes. The review highlighted that the students' graduate attributes were enhanced significantly due to the implementation of project-based learning under the context of the CDIO framework [17] and to the institutionalisation of internationalisation aspects [18]. This was backed up by positive feedback received from the School of Engineering's industrial advisory board members and electrical engineering alumni who confirmed that the curriculum responds to the market requirements of the wide oil industry in Kuwait that are related to electrical, electronics, instrumentation, process control and embedded systems.

On the other hand, the review process identified areas of improvement which can be summarised as follows. First, the curriculum lacks elective courses, which resulted in a rigid study plan that does not allow the student to identify and select the stream he/she would like to focus on during his/her study. Second, other than English, mathematics and science requirements, the curriculum lacks courses in general disciplines, such as arts and humanities as all other courses are electrical engineering departmental requirements. Third, the project-based learning that is currently applied is course-based, where a particular course, for instance, the Computer Programming course, is delivered as project-based learning instead of traditional face-to-face lecture-based course. This PBL approach restricts the framework of the projects, which must address the technical learning outcomes of the course, and hence reduces the chances of exposing students to wider multidisciplinary projects which are essential to further enable their potentials and to satisfy their ambitions.

NEW CURRICULUM STRUCTURE

The new curriculum structure presented here, preserves the 2+2-year model while addressing the weaknesses highlighted previously. It incorporates two flexibility degrees of freedom which are elective courses and an enhanced PBL approach. It aims at satisfying a flexibility ratio of 1:3 where almost 33% of its credit hours are mainly controlled by the students.

The First Degree of Freedom: Elective Courses

Besides mandatory courses, elective courses are introduced in the curriculum at three levels: college, school and department. This allows simplifying the introduction of new courses that are required by the dynamic market. It could be a general course (college elective), an engineering-oriented course (school elective) or a more specific engineering course related to a particular engineering specialty (department elective).

Table 1 and Figure 2 summarise the credit hours' distribution over college mandatory and elective requirements, school mandatory and elective requirements and department mandatory and elective requirements of the electrical and electronics engineering 2+2 programme.

As illustrated, 23% of the graduation credit hours' requirements of a Bachelor of Technology in Electrical and Electronics Engineering are embedded in elective courses with the highest percentage for departmental electives (12%) as the electrical and electronics engineering field is highly dynamic. On the other hand, the school electives' percentage may seem relatively low (4% only) in the new curriculum, and may lead to the early conclusion that there is not enough flexibility in terms of general engineering knowledge and skills requirements. However, at this stage, one cannot conclude on this aspect until the second degree of freedom is incorporated in the study.

Table 1: Credit hours' distribution of the new electrical and electronics engineering 2+2 programme.

		College requirements		School requirements		Department requirements		Total credit hours
		Mandat.	Elect.	Mandat.	Elect.	Mandat.	Elect.	
Diploma	Credit hours	2	6	31	0	29	0	68
	% (68 credit hours)	3%	9%	46%	0%	43%	0%	100%
Bachelor	Credit hours	0	3	6	6	35	16	66
	% (66 credit hours)	0%	5%	9%	9%	53%	24%	100%
2+2 programme	Credit hours	2	9	37	6	64	16	134
	% (134 credit hours)	1%	7%	28%	4%	48%	12%	100%

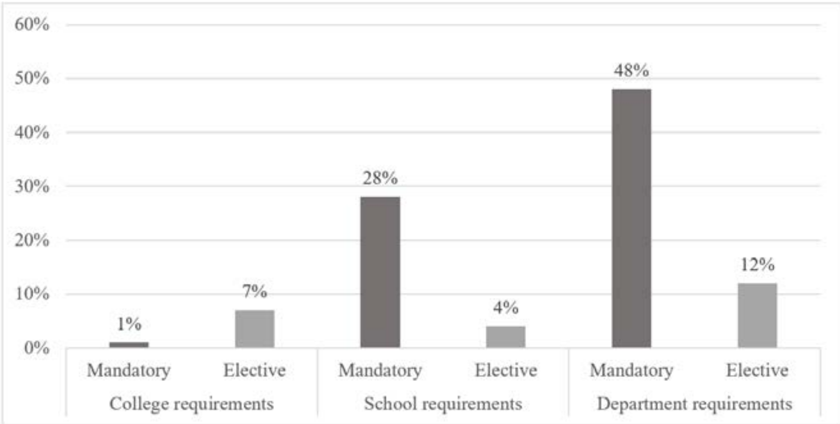

Figure 2: Credit hours' distribution of the new electrical and electronics engineering 2+2 programme.

The Second Degree of Freedom: Project-based Learning

PBL was implemented in ACK for the first time in the fall 2015 semester. At this early stage of implementation and for the sake of a smooth induction of this new learning strategy, the course-based PBL approach was adopted. This means that courses that best match PBL were selected in the existing curriculum and delivered using PBL concept. For instance, in the electrical engineering Bachelor programme, the courses that were and are still being delivered as PBL are introduction to computing with C++, programmable logic controllers, microelectronic design tools and embedded operating systems.

As can be noticed, these courses rely heavily on practical experience, which explains their selection as candidates for PBL. Since then, many improvements to the PBL implementation at ACK were studied, particularly those related to the assessment strategy, which is considered one of the main challenges of implementing PBL at ACK [19][20]. Nevertheless, this course-based PBL approach restricts its implementation to specific subjects, especially that the selected project must allow the coverage of all the technical and non-technical course's learning outcomes. This reduces the possibility of introducing multidisciplinary PBL projects, which are more frequent to occur in real-life engineering workplaces. Therefore, the new curriculum considers a new PBL approach that fosters the learning of interdisciplinary knowledge simultaneously with personal and interpersonal skills, product, process and system building skills.

This new PBL approach is inspired by the PBL model presented by Edström and Kolmos [21] yet, has its own structure. It consists of incorporating three pure PBL courses in the curriculum called Project 1, 2 and 3 in addition to the senior graduation project. Each of these projects requires one academic semester to be completed, except for the graduation project which requires a full academic year (i.e. two semesters). Hence, an engineering student starts the PBL journey in the last semester of his/her diploma studies and continues this experience in the Bachelor programme until his/her graduation. As their names suggest and as depicted in Figure 3, a PBL project is no more specific to a particular subject.

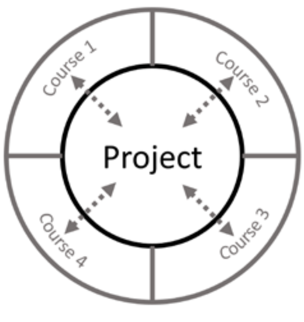

Figure 3: PBL project-linked courses.

Instead, it is a general project that may allow the students to apply elements of the courses they are taking simultaneously with the project or alternatively, could be independent of the disciplines in these courses and has its own learning outcomes. This depends mainly on the nature of simultaneous courses taken by the students in the same semester.

The new PBL approach also allows the students to conceive their own projects as per their passion and learning interests. It allows more flexibility and enables importing external projects from local, regional or international industries into the curriculum, and hence creating more realistic engineering workplaces on campus.

Table 2: The new study plan - semester 1 and 2 of the Bachelor of Technology in Electrical and Electronics Engineering.

Semester	Course code	Course name	Credit hours
1	SC310	Engineering Mathematics III	3
	EE310	Linear Integrated Circuits	3
	EE350	Wireless Communication Systems	3
	EE351	Signals and Systems	3
	EE390	Project 2 (PBL)	3
	EE319	Linear Integrated Circuits Laboratory	1
	EE359	Signals and Systems Laboratory	1
2	SC311	Engineering Mathematics IV	3
	EE340	Electric Machines & Drives	3
	EE391	Project 3 (PBL)	3
	EE349	Electric Machines & Drives Laboratory	1
	-	College Elective 3	3
	-	School Elective 1	3

Table 2 lists the study plan for the first year of the Bachelor of Technology in Electrical and Electronics Engineering. As can be seen, Project 2 is surrounded by simultaneous courses in the field of communication, linear integrated circuits and signals and systems, which allow Project 2 to be oriented towards signals, electronics and communication systems and to serve the courses in the same semester. As for Project 3, it is a more multidisciplinary project that serves the needs of all the students in this semester whatever the elective/mandatory courses they select. The enhanced PBL approach in the new curriculum allows to consider all PBL mandatory credit hours in the flexible category. This adds 15 credit hours to the flexible category and the curriculum flexibility ratio increases by 11%.

Overall Flexibility Ratio

As detailed earlier, elective courses occupy 23% and projects occupy 11% of the total 134 credit hours' graduation requirements in the new curriculum. Hence, one can assume that the flexibility ratio of this new curriculum is estimated to 1:3 (34%). As for the distribution of the flexibility ratio over college, school and department requirements, the 11% implicit flexible credit hours added by PBL department mandatory courses should be further divided as follows:

- college: 1% in the form of social responsibilities, communication, etc;
- school: 5% in the form of engineering personal and interpersonal skills, and product, process and system building skills;
- department: 5% in the form of disciplinary knowledge and skills.

When PBL credit hours are added to elective ones per category then compared to traditional lecture-based mandatory courses, the results are those depicted in Figure 4.

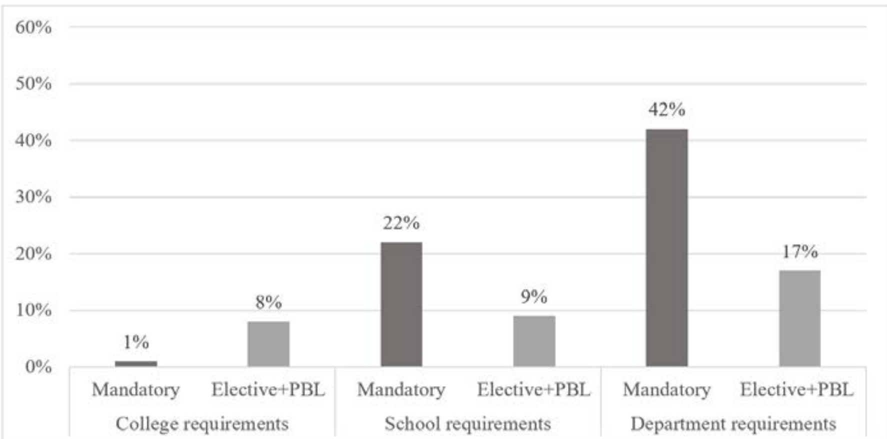

Figure 4: Flexibility ratio distributed over college, school and department requirements.

This figure shows clearly that the flexibility in the new curriculum is equally balanced between the department credit hours (17%) and general college and engineering credit hours (8 + 9 = 17%). Hence, whatever the market new requirements are, related to technical or non-technical subjects, the new curriculum can smoothly accommodate them.

DISCUSSION AND CONCLUSIONS

The traditional one-to-many teacher-centered learning approach is no more a sustainable solution for delivering quality higher education that responds to the dynamic market demands. Nowadays, higher education institutions are focusing on student-centered approaches where the student, to a given extent, has control over his/her learning process. Therefore, in the recent past years, many learning techniques have emerged, such as distance learning, e-learning, project-based learning (PBL), conceive design implement and operate (CDIO), etc. These strategies enable one or more learning degrees of freedom, which are usually classified under *when*, *where*, *what* and *how* to learn categories.

The School of Engineering at the Australian College of Kuwait (ACK) has started to incorporate the student-centered approach since 2015 by implementing PBL and then being an active member of the CDIO initiative. Although PBL added significant enhancements to the ACK graduates attributes, the currently implemented PBL approach restricts its implementation to course specific projects, and hence reduces the potential of addressing realistic industry-based engineering multidisciplinary projects. Furthermore, the curriculum structure is rigid and the student has no control over *what* to learn. As such, the flexibility of the curriculum was mainly restricted to the *how* to learn only.

This article also addressed shifting the flexibility from the *how* to learn to the *how* and *what* to learn categories simultaneously. The authors discussed two degrees of freedom that allow the engineering curriculum in the School of Engineering at the Australian College of Kuwait to be more flexible and adaptable to the dynamic market needs. To incorporate the *what* to learn flexibility, elective courses have been introduced at the college, school and department levels to allow flexibility in all aspects of knowledge, competencies and skills required by a future engineer. In addition, an enhanced PBL approach that is more multidisciplinary-project-oriented was presented which in turn also adds flexibility, not only to the *how* to learn category but also to the *what* to learn category.

At a second stage, the flexibility ratio was defined as the *flexible* credit hours taken by a student over the total credit hours required by the student as a graduation requirement. This ratio was estimated to 34% and was proven to be equally balanced between the general and engineering requirements from one side and the discipline requirements from the other side.

Upon the implementation of the new curriculum presented here, the students would be given sufficient control over *how* and *what* they learn. Other flexibility aspects that need to be addressed in the near future, are the *when* and *where* to learn especially that the Covid-19 pandemic has drastically changed the society’s acceptance level of on-line and distance learning after being somehow forced to accept due to a *force majeure*.

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