UNIVERSITY-INDUSTRY COLLABORATION THEMES IN STEM HIGHER EDUCATION: A EURO-ASEAN PERSPECTIVE

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ABSTRACT

This paper analyses University-Industry collaboration models in Science, Technology, Engineering and Mathematics education. First, a review of published CDIO optional standards for University-Industry collaboration is presented. With strong industrial link requirements, the French related standards for engineering accreditation are then scrutinized and echoed with European requirements. To broaden the perspective, the Swedish and Thai quality criteria for industry links are also reviewed. As a result, five identified University-Industry collaboration themes and criteria of requirements are mapped in a table. Three new emergent themes are also identified based on questionnaires and interviews operated during fall 2019 in the context of a Euro-ASEAN capacity-building project. By identifying themes of collaboration with industry and business, the analysis of this paper lay the foundation of a structured relationship model for STEM universities, to be fueled later by shared good practices among countries. The eight proposed University-Industry themes could indicate directions of development to the CDIO framework for specific optional standard definition, at a relatively high level. This paper may also contribute to advancing 4.0 STEM-educational frameworks for curriculum guidelines aligned with skills for industry.

KEYWORDS

Relationship between Academia and Industry, Work Integrated Learning, Continuous Improvement of Education, STEM, CDIO optional Standards, Standards 1

CONTEXT: NOT PRESCRIPTIVE STEM-EDUCATIONAL FRAMEWORKS

New skills are required in the era of the Fourth Industrial Revolution, now also for the post-COVID-19 era (or with-). As stated by Skills Development Scotland & Centre for Work-based Learning (2018), skills 'serve as the bridge between knowledge and performance. (…) This bridge is every learner’s path to success’. From the perspective of STEM universities (Science, Technology, Engineering, and Maths) and engineering educational institutions, it is crucial to meet new industry expectations in curricula. Institutions are to offer education focused on students’ needs but also labour market needs. For proactive alignment of STEM training models with industrial requirements, University-Business-Industry Collaboration (UBIC) is a top concern within educational frameworks.

UBIC Models in CDIO Optional Standards 3.0 Since 2017

In 2017, Rouvrais, Remaud, and Saveuze suggested a potential CDIO new standard to sustain Industry-University partnerships, in addition to a dedicated rubric as a maturity scale for assessment. In engineering education, the CDIO international framework relies on twelve non-prescriptive standards for curricular planning and outcome-based assessment. In this suggestion, partnerships with various types of companies (regional, national, and international) are ‘to be in place in the institution and within the formal integrated curriculum. Adequate models of WBL (European Commission, 2016) are to support student competency development of the product, process, system building, knowledge, personal and interpersonal skills, so as of company social contexts and related professional responsibilities.’ As a rationale, the curriculum and learning outcomes are designed with authentic pedagogical approaches, in and out of the formal curriculum. Students recognise STEM professionals and especially engineers as role models. With WBL experiences for their students (Rampersad, 2015), faculties are more effective in contextualising their lessons and can better prepare their students to meet the demands of the engineering profession and to become lifelong learners.

In 2018, Cheah and Leong proposed then to extend the CDIO standards in connection with the new manufacturing landscape. After analysing the relevance of each of the twelve CDIO standards to Industry 4.0, the authors recommended two additional standards, along with dedicated rubrics for assessment. The first one industry engagement is defined as ‘Actions that the education institution undertakes to actively engage industry partners to improve its curriculum (…) to make explicit the necessity of actively seeking industry feedback not just in designing curriculum, but also in delivering them’. The second is on Workplace Learning and defined as ‘A curriculum that includes students working in a real-world work environment with the aims of strengthening campus learning and developing their professional identity. (…) In the workplace, the acquisition of knowledge or skills can occur via both formal and informal means.’

UBIC Models in Suggestive European Frameworks

In 2015, the European QAEMP collaborative project (Bennedsen et al., 2018) introduced in its evaluation handbook three criteria related to University-Industry collaboration, among 27 for cross-evaluation of science and engineering programmes. The first was on stakeholder input, with as rationale ‘programme development takes place in a way that engages a range of internal and external stakeholders e.g. Industry Advisory Board and Benchmark Statements. This ensures that the programme is ’fit-for-purpose’’. A second criterion was on 'opportunities should be provided at points in the programme to allow students to engage in work-based activities'. A third was on links to employability, with as rationale 'a frequent contextualisation of the learning experiences with respect to future employment possibilities is taking place, (…) to ensure students have the opportunity to develop their ideas about possible careers’.

In 2020, a European initiative suggested the Curriculum Guidelines 4.0 (PwC, 2020) to promote better cooperation between industry and education and training organisations. The focus is on the alignment of Advanced Manufacturing Technologies education and training with the needs of the New Industrial Age. Eight dimensions are considered, one is in collaboration to 'promote practices that move beyond the typical institutional collaboration patterns, by engaging individuals and communities'. The conceptual principles derived include the following: further increasing university-industry collaboration in terms of both volume and diversity of collaboration forms (e.g. internships/apprenticeships, mentoring, project banks, think tank competitions, summer schools, etc.); acknowledging the role of industry partners as educational, research and employment partners, and ensuring their engagement in the full student's learning experience, including strategy development; creating effective learning ecosystems that engage all key stakeholder groups, including education & training providers, industry, policy-makers, supporting structures and the broader community.

UBIC MODELS IN SOME EU AND THAI ACCREDITATION REFERENCES

Aside indicative educational frameworks for internal quality enhancement, more prescriptive accreditation systems include standards and criteria for external evaluation and labelling.

French Engineering Education Themes

As a Quality Assurance (QA) organisation, the *Commission des Titres d'Ingénieur* (CTI) was established under French law in 1934, with strong industrial link requirements. CTI's board membership comprises 50% of employers and professional engineers' representatives. In France, an engineering graduate school must establish partnerships with counterpart institutions and its stakeholders, particularly employers, industries and communities. The CTI references and guidelines serve for periodic assessment and accreditation, as authorisation to grant the Award of *ingénieur diplômé*. The latest English version (CTI, 2017) is used hereafter to identify the formal UBIC requirements, with verbatim text in quotation marks:

- A formal UBIC requirement to integrate industrial partners in programme design and operation: in the standard B on external links and partnerships, CTI strongly recommends that 'the engineering programmes have established lasting and mutually beneficial relationships with industry. Active professionals are involved in the school's bodies as well as in the design and implementation of programmes' (CTI, 2017). In the standard C on design and follow-up of the training project, CTI also recommends that 'the school has advisory committees comprising professional representatives and alumni; students may participate. For each programme, the committees provide advice for follow-up and update the curriculum' (C2), and 'there is a clear formal process for the design and approval of new engineering programmes. The programmes are regularly reviewed and updated to assess their relevance (C2.3)' (CTI, 2017). 'Significant training time is provided by professionals from the corporate world (e.g. guest lectures) in the University workspaces for theory/practice balance' (C5.2), with a quantitative minimum percentage required. Active professionals are involved in the implementation of programmes (CTI, 2017), a quantitative threshold is fixed;
- A formal UBIC requirement to facilitate Work Placement of students during the curriculum: in the standard C on industry and research internships, CTI requests that 'curriculum include learning experiences which enable the development of practical skills to enhance graduate employability and strengthen the links with industry, […] programmes […] should comprise a significant amount of industrial experience throughout the curriculum, mainly in the form of internships in the industry' (CTI, 2017). Learning experiences that contribute to practical training are to include:

- Internships in the industry: a compulsory integrated internship period for all programmes and students of 28 weeks minimum, with ECTS credits;
- Learning activities that reproduce real-life experiences (projects with industrial partners directly involved, simulations and industry games);
- Industry visits, and seminars organised by industry representatives (CTI, 2017);

- A formal UBIC requirement to analyse graduate employment & employability: in the standard E on graduate employment, CTI strongly recommends that 'the school has an organised approach to surveying and analysing the development of the job market and the employment of engineers' (CTI, 2017). For employment and employability analysis at programme level, 'Surveys are periodically conducted to collect and analyse information on the employment and careers of engineers in general, and more specifically on the employability of degree programme graduates (time to the first job, level of wages, area of activity, etc.)' (CTI, 2017);
- A formal UBIC requirement to prepare students for employment & careers: in the standard E2, CTI recalls that 'the school promotes career guidance and job preparation for future graduates. It values the creation of professional businesses by the engineering students and supports them' (CTI, 2017). In Criteria C5.2, individual orientation activities and coaching is provided by professionals.

European Level Themes for Accreditation

From 2012 to 2015, the European Ministers of the European Higher Education Area gave as a priority for working to improve employability, learning throughout life, the ability to problem-solving, entrepreneurial skills, through enhanced cooperation with employers, especially for the development of training programmes. This formal recommendation applies to all Higher Educational Institutions (HEI) and fields and it has a special resonance for the training of STEM learners in universities. To contribute to the common understanding of QA for learning and teaching across European borders, the Standards and Guidelines for QA of the European Higher Education Area (ESG) were set in 2012. Accordingly, as an instance, the French *Haut Conseil de l'évaluation de la recherche et de l'enseignement supérieur* (Hcéres) set criteria for research-led universities, including their educational programmes and research labs. But the ESG criteria are less complete than for accredited engineering programmes much more industry-oriented, as with CTI in France. In another European country, the Swedish QA system is not strictly aligned with the ESG. The Swedish Higher Education Authority (UKÄ, 2020) proposed an assessment area on Working Life and Collaboration, but with one criterion only, at programme level for engineering. The area is more a recommendation than indicated formal requirements, as written in the assessment procedure: 'The HEI has well-functioning collaborations with the labour market and with the surrounding society that help improve the courses and programmes. Working life and collaboration are systematically factored in as part of the HEI's quality system and quality work. Using information produced within the quality system, the HEI identifies needs for the development of working life and collaboration elements in its education. The HEI implements measures and improves the programmes to ensure they are useful, and continuously develops students' preparedness to face working life. The HEI has systematic procedures and processes for ensuring that planned measures or implemented measures are appropriately communicated to relevant stakeholders, both internal and external' (UKÄ 2020).

On a pan-European level, the European Network for Accreditation of Engineering Education (ENAEE) aims at building a framework, to enhance the quality of engineering graduates and to facilitate the mobility of professional engineers in Europe. ENAEE evaluates the policies and procedures implemented by accreditation and QA agencies that have applied for authorisation to award the EUR-ACE® label to the engineering degree programmes which these agencies accredit (e.g. CTI). In collaboration with industry, accreditation agencies should confirm to ENAEE that their HEIs (verbatim):

- Achieve the programme aims, which must reflect the needs of employers and other stakeholders (ENAEE, 2015, sec. 2.4.1). The aims should take into account employment opportunities for graduates and the needs of employers. For such, are the relevant industry and labour market organisations and other stakeholders consulted? Is the methodology and schedule of consultation adequate to identify educational needs? Have the stakeholders' educational needs identified in a way which facilitates the definition of the programme aims and programme outcomes? Are these aims and outcomes described in terms of professional competence profiles and functions/roles/activities expected?
- Provide a teaching and learning process that enables students to demonstrate achievement of Programme Outcomes; if the programme includes time spent in the industry, it should be assessed in the context of its contribution to the achievement of the Programme Outcomes (ENAEE, 2015, sec. 2.4.2). Thus, are the partnerships with public and/or private bodies for training periods outside the university adequate, quantitatively and qualitatively, to the achievement of the programme outcomes?
- Comply with internal QA procedures. Processes of engineering graduate placement monitoring are in place. Thus, do the results of the monitoring of the engineering graduates' job placement and the employed graduates' and employers' opinions on the graduates' education provide evidence of the qualification's value, of the appropriateness of the programme aims and the programme outcomes to the educational needs of the labour market? (ENAEE, 2015, non-prescriptive Appendices sec. 5.5);
- Provide adequate resources. Assistance with external placements should be readily accessible by students (ENAEE, 2015, sec. 2.4.3). Thus, does the programme provide student support services (career advice, tutoring and assistance) relevant to the learning process and enable students' learning and progression easier?

UBIC Thai Criteria

The Thai government provides funding for the public universities to develop degree and non-degree programmes that can produce the graduates equipped with professional competency i.e. STEM skills as well as 21st-century skills. This is to prepare a high-quality workforce that can serve industrial needs for Thailand 4.0 policies. The regulation is ensured by Thailand's Office of the Higher Education Commission (OHEC, 2014) and the Office for National Education Standards and Quality Assessment (ONESQA, 2018). ONESQA has a broad scope and does not provide strategic plans for the industry linkage, being at the institution level, it does not provide UBIC details at the programme level. For work-integrated learning is the policy at the Ministry and university levels.

In Thailand, there is a UBIC linkage in terms of curriculum development, credited and uncredited internships, and learning activities. The industry provides feedback as stakeholders and evaluates the university graduates whether they are well equipped with both hard and soft skills for the jobs in their sectors. The Thai government has launched many programs to involve the industry aiming for enhancing students' learning experience. For instance, the Thailand Science Research & Innovation has launched the Industrial & Research Projects for Undergraduate Students programme, which provides funds for undergraduates to work and help solve industry-based problems in Thai factories/industries. The learning activities echoing UBIC mostly involve project-based learning in the fourth year of undergraduates to complete science and engineering degree requirements. Furthermore, a ‘Talent mobility’ program was established to assist both undergraduates, and postgraduates to research on industry-based and problem-based learning by providing financial support and also matching demands and interests between university researchers and the industry.

In Thailand, some industries and university alumni also participate to host undergraduates during their third year of the degree programme to work as apprentices for 2–3 months. The internships can also be credited to some degree programmes, according to each curriculum regulation and requirement fixed by the university. Furthermore, some programmes offer cooperative education, where students can be trained in the industries as staff for at least one semester. Each student is supervised by both a mentor from the company and a teacher at home university.

UBIC MAPPING

In suggestive frameworks for STEM education (e.g. CDIO optional standard suggestions and Curriculum Guidelines 4.0), UBIC common themes are thus including Partnerships and Industry Engagement in designing and operating curricula, Workplace and Work-based learning. The QAEMP project added Links to Employability. For prescriptive accreditation standards and criteria (e.g. French CTI, ESG, UKÄ, ENAEE), UBIC themes differ, and sometimes also include employment analysis (e.g. tracer study) and career preparation courses. UBIC recommendations or formal requirements are at different levels. They could be partially required (P), largely required (L), fully required (F), or even not required (N) when no elements are explicitly provided (cf. NPLF scale of ISO33020). A mapping of themes to structure and exemplify UBIC models for Continuous Improvement of STEM Higher Education and Engineering Education, by columns of reference sources, is proposed in the next Table, with its NPLF subjectivity as written requirements in the literature are sometimes ambiguous and interpretative and may not reflect reality. It consists of the following selected themes, bylines, resulting from the previous section analysis:

- UBIC-1: Industrial and Business partner’s implication in STEM programme design, review & revision;
- UBIC-2: Industrial and Business partner’s participation in STEM programme teaching & learning activities;
- UBIC-3: Professional work activities integrated in STEM curricula;
- UBIC-4: Graduate Employment & Employability Analysis at STEM Schools;
- UBIC-5: Students Preparation for Employment & Careers in STEM programme.

Table 1. Tentative Mapping of UBIC Themes in some Frameworks Applicable to STEM Education, NPLF requirements according to ISO33020 scale.

NPLF req. scale	CDIO (Rouvrais & al 2017)	CDIO (Cheah & Leong 2018)	QAEMP (Bennedsen & al 2018)	Guidelines 4.0 (PwC 2020)	France (CTI 2017)	Sweden (UKÄ 2020)	EU (ENAEE 2015)	Thailand (ONESQA 2011)
UBIC-1	L	L	L	N	F	P	F	L
UBIC-2	L	N	N	L	F	N	N	P
UBIC-3	L	L	L	L	F	N	L	L
UBIC-4	N	N	N	N	F	P	F	L
UBIC-5	N	N	L	N	L	N	L	N

As a discussion, for some UBIC criteria, indicators and thresholds for achieving the so-called excellence are different. Even if incorporating involvement of academic staff, students, and other stakeholders is classical in periodic STEM programme design & revision in most universities, the profound implication of industrial partners can be rather partial (P), quantitatively in the process and decision committees for UBIC-1. For example, Thai QA has reflected industrial and business partners' implications in programme design & revision for curriculum development that has to be done every five years with comments and feedback from industries as one of the stakeholders. To report annually if most Thai public institutions send questionnaires to industries which are employers of some of their graduates to meet ONESQA Criterion 2 (indicators on employability in one year after graduation and employer satisfaction), the formal requirements remain rather partial (P) or empty (N) on other UBIC themes, quantitatively and quantitatively. The quality of research is the main concern. In Thailand, universities also provide cooperative learning which is a collaboration between academic and industry partners (UBIC-3), most curricula accredit vocational training of third-year students. The industry partners take part in mentoring on special projects for fourth-year students. As another example, the formal level of requirements for work placements by French CTI during the curriculum is high (F), with a minimum of 28 weeks (internship compulsory and ECTS credited for all students), including mature processes in place at the institution level.

A EURO-ASEAN COLLABORATION TO SHARE UBIC GOOD PRACTICES

In light of the global fourth industrial revolution era, high quality STEM education is seen as a critical success factor for ASEAN countries' economic growth. In that context, the EASTEM (Euro-Asia Collaboration for Enhancing STEM Education 2019-22) capacity-building project, aims at improving the employability of STEM graduates from ten partner universities by ensuring students acquire skills needed in the workplace. With the knowledge exchanged through the EASTEM partnership, each partner's expertise and experience synergistically enrich each other, and will in turn subsequently benefit all partners. This includes developing strategies for enhancing their STEM education system, to establish a platform for networking on STEM education, and to safeguard the pitfalls of education in rapid changes in science and technology.

The project consortium includes three universities in Europe and ten universities in Thailand, Indonesia, and Vietnam. In EASTEM, most of the STEM programmes under focus are at BSc levels, in 4 years. In that context, methods and tools are already developed for fostering competence integration in STEM programmes and for establishing STEM centres at partner universities. Overall, 17,399 students enrolled are in the scope of EASTEM impacts in ASEAN partners in the short term.

Most universities in Thailand are members of the Council of University Presidents of Thailand (CUPT), and they tend to apply CUPT for quality assurance. CUPT QA at programme level adopted the ASEAN University Network-Quality Assurance, as in Vietnam and Indonesia. The eleven criteria developed in the third version of the AUN-QA model for programme level (Pham et al. 2020) will be studied further in the EASTEM project, as it was done with ENAEE standards for regional levels. As an example, AUN-QA criterion 2 recommends that programme learning outcomes are formulated based on stakeholders' needs. The industry and business partners are the main stakeholders. Out of the scope of this paper, two other national ASEAN Higher Education Quality Standards which include some UBIC assessment areas are under review as well (i.e. Vietnamese Bộ Giáo dục và Đào tạo criteria and Indonesian BAN-PT with its recent flexibility to learn outside the study programme called Kampus Merdeka).

Additional UBIC Themes Also Fitted to ASEAN Local Needs

EASTEM partner universities have enthusiasm to establish or reinforce UBIC themes in their STEM education to better serve the industry and community needs. Nevertheless, the integrated approach and its ecosystem for local impacts have yet to be created and promoted among students, faculty staff, and communities. To broaden the perspective of the UBIC mapping, a qualitative analysis had been run with university partners from two different European (France and Sweden) and the three ASEAN countries. In the first phase, partners were asked what the new missions for their STEM Faculty/Schools or the ones could be to be reinforced within the 3–5 years. The five UBIC themes presented earlier were recognised as missions to be reinforced in priority by most of the partners. Based on questionnaires operated in the fall 2019 and ongoing semi-structured interviews, additional themes and good practices of UBIC models were then identified. Thirty-eight new missions were collected and used to identify new themes or subthemes. Around 50 strengths and 40 weaknesses were collected on the UBIC themes. The philosophical stance is interpretive, to prevent personal bias from influencing, as we emphasise the meanings University STEM programme leaders and deans confer upon their institutional contexts. Three additional UBIC themes were put to the light by partners with the following potential missions:

- UBIC-6: Financial aspects with Industry (strategic QA): public funds are under pressure and external sources will permit to better prepare a high quality workforce to serve industrial needs for ASEAN 4.0 policies: to collect external financial support & resources, to obtain financial support from industrial partners for STEM activities, to foster scholarship from industrial sectors, and to receive support for STEM teaching tools from companies and alumni are keys;
- UBIC-7: Innovation and R&D with Industry (functional QA): a few years ago, some analysis of research development & technology (based on paper publications and patents) in Thailand and south-east Asia (except Singapore) reflected that the research does not strongly contribute to industry development in the country: to develop a research platform for university-industry, to attract the companies setting up R&D centres in University, to integrate industrial environment and startup ecosystem into the campus, and bring students into the incubation, and to collaborate with the industrial partners on human resource capacity building and innovative startup development are keys;
- UBIC-8: Workspaces with Industry (echoing CDIO standard 6): to increase/enrich learning infrastructure and facilities, to obtain support for improving education facilities, to create a real-life learning environment from companies for students, and to receive support from companies that experiential and creative learning spaces for students are keys.

The qualitative analysis opens up new prospects, e.g. the need to investigate further on guiding partners on how to integrate competence development for students into STEM education programmes and university strategies by engaging with deans, vice-rectors and rectors, echoing CDIO standard 1. With the knowledge to be exchanged and capitalised in the next phase via focus groups and workshops with high-level University representatives, ASEAN partner institutions may acquire the capacity to develop their processes for continuous integration of competence development aspects into their educational programmes and university strategies and policies, including the 5 + 3 UBIC themes identified.

DISCUSSION AND INSIGHTS

Requirement and maturity levels in UBIC models differ greatly between the countries and institutions (e.g. prescriptive with quantitative minimums, quality assured formal processes to be in place) and are part of the international diversity, culture, educational and industry history, and national economic growth. In the EASTEM project, good practices are already identified and categorised according to UBIC themes, with collaborative support from the university management of the EASTEM partners. One objective is that STEM programmes will be more sustainable and partner institutions better equipped to interact with corporate partners in the development of their STEM-university education.

The results of this paper could echo strategic plans and policies on higher education in two communities. First, with eight UBIC themes categorised and mapped, this paper may contribute input to advance the CDIO framework's optional standards with UBIC. Recently, the CDIO council recommended a 'deeper analysis of the proposals industry engagement, workplace learning and workplace and community integration, considering several alternatives: Integration into the texts of core standards, merging or separate elaboration. This is essential future work' (Malmqvist et al., 2020). Secondly, within the EASTEM international partnership in the ASEAN 4.0 contexts (WEF, 2017), to sustain the change in the ten ASEAN partners on a strategic level, updated university strategies on UBIC will be stimulated, echoing CDIO standard 1. University and industry competency alignment for the new Industrial Age is now a consideration, but strategies, priorities, regulations, culture of change, and problem facing differ. But for enhanced UBIC, Industry and Academia values and actions need, however, to be shared, and collaboration reinforced. Resistance factors remain as stated by Morell (2014): 'Industry and academia have different cultures, different values, different needs and different expectations. (…) The biggest barrier that may exist is the failure to recognise that each sector has different needs.' In EASTEM partnership, by engaging with deans, vice-rectors and rectors in each institution, hopefully, UBIC models and guidelines are to be shared for proposing a reference model on governance including UBIC strategies and missions (strategic QA rather than functional QA only). For partners to effectively start or reinforce their competence integration process in their selected STEM programmes and STEM centres, aligned with industrial needs, reaching collaborative conclusions on how to adapt programmes with UBIC in the EASTEM framework is now a prospect.

Worth to be noted, the COVID-19 pandemic will change the future of work and students' employability and careers. As recently argued by Fernandes (2020), 'a global recession now seems inevitable. But how deep and long the downturn will be (…) also depends upon how companies react and prepare for the restart of economic activities.' How do STEM higher education systems cope with and will recover from the crisis? UBIC themes in STEM education in the post-COVID-19 are to be further explored.

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