APPLICATION OF CDIO IN NON-ENGINEERING PROGRAMMES – MOTIVES, IMPLEMENTATION AND EXPERIENCES

Johan Malmqvist

Chalmers University of Technology, Gothenburg, Sweden

Helene Leong-Wee Kwee Huay

Singapore Polytechnic, Singapore

Juha Kontio

Turku University of Applied Sciences, Turku, Finland

Trinh Doan Thi Minh

Vietnam National University (VNU-HCM), Ho Chi Minh City, Vietnam

ABSTRACT

The aims of the paper are to present a set of general recommendations for how to implement CDIO in non-engineering programmes, to show how they can be applied in practice, and to discuss associated benefits and challenges. The application of the recommendations is demonstrated in case studies of non-engineering programmes that have implemented CDIO. The subject areas of the programmes include art, science, food processing, business, and library science. The case descriptions are purposively relatively detailed aiming to enable a transfer of approaches and experiences from the cases to other non-engineering programmes. Common benefits of applying CDIO to non-engineering programmes include a stronger connection to the professional context, and strengthened programme development and quality assurance. Common CDIO implementation challenges for non-engineering programmes are found to be similar as for engineering programmes, for example, the training of faculty to teach skills beyond their subject specialty, such as design and communication.

KEYWORDS

Curriculum design, Non-engineering programmes, CDIO adaptation, CDIO standards 1 - 12

INTRODUCTION

CDIO originated in mechanical and aerospace engineering and is still dominated by engineering programmes. CDIO application in engineering has shown to be successful including positive effects on graduates' design, personal, and interpersonal skills, and outside perceptions of educational quality (Malmqvist et al., 2015). However, one may ask if CDIO is limited to application in engineering programmes, or may it be more widely applied? And, if so, how can this be achieved?

Crawley et al. (2014) argue that this is the case and claim that CDIO may also be applied to non-engineering programmes by:

- Developing a description of the profession's context of practice as a starting point for educational design (corresponding to CDIO standard 1)
- Working with stakeholders to identify their requirements on the graduates (CDIO standard 2)
- Adapting the pedagogical and curricular elements of CDIO (CDIO standards 3-11 mainly) to the discipline's needs
- Applying the CDIO curriculum development and quality assurance processes (CDIO standard 12)

Doan et al. (2014c) proposed the Generalized CDIO Standards as a version of the corresponding CDIO Standards by translating engineering domains into broad disciplines to make them more applicable to any programme. As seen in Table 1, in the seven essential CDIO Standards 1-3, 5, 7, 9 and 11, and in two supporting Standards 4 and 6, the term "*product and system lifecycle development and deployment*" has been generalized into "*profession's context of practice*", "*CDIO skills*" into "*professional competence*", and "*engineering practice*" into "*professional practice*", while Standards 8, 10, and 12 remained unchanged. Doan et al. also suggests that the tools designated in Table 1 can be helpful in adapting the generalized CDIO standards to specific programmes. Further, Malmqvist (2015) offers some examples of how to translate CDIO standards to non-engineering contexts, see Table 2.

However, whilst these principles and examples may offer some guidance for implementation of CDIO in non-engineering programmes, there is a lack of deeper descriptions as well as surveys of such implementations. Further, they only cover some of the CDIO standards. This paper aims to address this gap in the CDIO literature.

Specifically, the aims of this paper are to clarify:

- With which motives has CDIO been applied to non-engineering programmes?
- How this was achieved, including what modifications were made to contextualize the CDIO framework and tools to the situation?
- What were the effects of the CDIO implementation in these non-engineering programmes, including benefits, drawbacks and limitations?

The remainder of the paper is structured as follows: After this introduction, we first account for and motivate the research approach of the paper. This is followed by the case study section, were we describe six non-engineering programme that have implemented CDIO. In the discussion section, we compare the motives, implementations and experiences of non-engineering CDIO programmes. Finally, the paper is concluded.

Table 1. Generalized CDIO Standards and Tools for Implementation

<table>
<tr><th>CDIO Standards
(Crawley et al., 2014)</th><th>Generalized CDIO Standards
(Doan et al., 2014c)</th><th>Tools for Implementation
(Doan & Nguyen, 2014a, & 2014b)</th></tr>
<tr><td>1. The context</td><td>1. The context: Adoption of the principle that profession's context of practice is the context for education</td><td rowspan="2">Outcomes-Based CF's templates for
- Programme educational objectives
- Programme learning outcomes</td></tr>
<tr><td>2. Learning outcomes</td><td>2. Learning outcomes: PLOs constructed in form of four sections of the PLOs Syllabus at 4-level of detail for disciplinary knowledge; personal and professional skills and attributes; interpersonal skills; and professional competence, consistent with programme goals and validated by programme stakeholders</td></tr>
<tr><td>3. Integrated curriculum</td><td>3. Integrated curriculum: A curriculum designed with mutually supporting disciplinary subjects, with an explicit plan to integrate personal and professional skills and attributes, interpersonal skills, and professional competence</td><td>Outcomes-Based CF's templates for
- Programme ideas
- Programme plan
- Skill development routes
- Curriculum design matrix</td></tr>
<tr><td>4. Introduction to engineering</td><td>4. Introductory course: An introductory course that provides the framework for professional practice, and introduces essential personal and interpersonal skills</td><td rowspan="4">Outcomes-Based CF's templates for
- Course syllabus and plan
- Skill progression matrices</td></tr>
<tr><td>5. Design-implement experiences</td><td>5. Professional practice experiences: A curriculum that includes two or more experiences of professional practice</td></tr>
<tr><td>7. Integrated learning experiences</td><td>7. Integrated learning experiences: Integrated learning experiences that lead to the acquisition of disciplinary knowledge, as well as personal and interpersonal skills, and professional competence</td></tr>
<tr><td>11. Learning assessment</td><td>11. Learning assessment: Assessment of student learning in personal and interpersonal skills, and professional competence, as well as in disciplinary knowledge</td></tr>
<tr><td>6. Engineering workspaces</td><td colspan="2">6. Workspaces for professional practice: Workspaces and laboratories that support and encourage experiencing professional practice, disciplinary knowledge, and social learning</td></tr>
<tr><td>8. Active learning</td><td colspan="2">8. Active learning (unchanged)</td></tr>
<tr><td>9. Enhancement of faculty competence</td><td colspan="2">9. Enhancement of faculty competence: Actions that enhance faculty competence in personal and interpersonal skills, and professional competence</td></tr>
<tr><td>10. Enhancement of faculty teaching competence</td><td colspan="2">10. Enhancement of faculty teaching competence (unchanged)</td></tr>
<tr><td>12. Programme evaluation</td><td colspan="2">12. Programme evaluation (unchanged)</td></tr>
</table>

METHOD

A case study approach was chosen as the research method, with two main considerations in mind: First, we wanted to study and account for the programmes in some detail in the paper, enabling others to transfer insights and approaches to their own approaches. Second, there are still a related limited number of non-engineering CDIO programmes, making it difficult to apply quantitative methods such as questionnaires.

Table 2. Examples of translation of CDIO standards to non-engineering professional contexts

CDIO Standard		Domain	Translation
1	CDIO as Context	*Medicine & health technologies*	• Diagnosis, treatment planning, operation, post-operative care of patients • Design, operate & improve medical facilities and equipment
		Education	• Designing, carrying out and assessing the effects of learning experiences on students
		Business management	• Design, operate and improve organisations (companies)
4	First-year experiences	*Library science*	• Introduction course to the library and information service field, professions, work environments, services, national and international networks
5	Design-Implement experiences	*Music*	• Create commercial music (Singapore Polytechnic)
6	CDIO workspaces	*Advertising*	• Student-driven advertising agency (Singapore Polytechnic)
7	Integrated Learning Experiences	*Medicine & health technologies*	• Explain surgical procedure to patient • Interview patient about prior history

The paper is based on case studies of the following six programmes:

- ***Food Science and Technology*** and ***Music and Audio Technology*** at Singapore Polytechnic, Singapore
- ***Business*** and ***Library and information Services*** at Turku University of Applied Science, Finland
- ***Chemistry*** and ***International Business*** at Vietnam National University-Ho Chi Minh City, Vietnam

The selection of case studies was made in order to cover a broad span of non-engineering programmes, including science, business, performing arts and other areas. For each of the programmes, we review its main goals profile and contents, its CDIO implementation and the positive and negative effects associated with its CDIO implementation.

CASE STUDIES

In this section, we describe the CDIO implementations of six non-engineering programmes. We start by reviewing the educational context and overall strategies of their host universities, and then move on to the specific programmes. The presentation discusses motives, the actions carried out in the CDIO implementation processes and the resulting effects, including benefits, drawbacks, and challenges.

Singapore Polytechnic, Singapore (SP)

Singapore Polytechnic has been a CDIO collaborator since 2004. Since then, the institution has adapted the CDIO framework for the institution-wide initiatives and, through these initiatives, applied the CDIO framework to non-engineering programmes like the Diploma in Music and Audio Technology.

Music and Audio Technology programme at Singapore Polytechnic, Singapore

The Diploma in Music and Audio Technology (DMAT) aims to provide foundational skills so that graduates can create music and audio content for the media industry. After implementing the programme for a few years, the programme team realized that they needed to systematically develop 'generic' skills in their students. They adopted the CDIO approach to infuse teamwork, oral communication, written communication and thinking skills into selected courses in the programme.

The CDIO syllabus v1.0 (Standard 2) was used as a basic template for the design of the programme. Technical learning outcomes relating to music and audio competence were first selected and articulated. Learning outcomes for teamwork, oral communication, written communication and thinking skills were then added to the programme's syllabus. The learning outcomes were then mapped to specific courses within DMAT. A distinction was made between where the skills needed to be explicitly taught and assessed, and where they were used. Care was taken to find courses where the generic skills could naturally be infused into the learning activities.

Initially, integrating the teaching of soft skills (Standard 7) into the various courses posed problems with some staff. There was a feeling among some lecturers that they were not qualified to teach certain topics, such as written communication. Coming up with appropriate learning activities to infuse these skills involved research, training and ingenuity on the part of the lecturers (Figure A1). Holding regular meetings/sharing sessions, where lecturers would show the learning activities in their course, helped this process. The benefit of explicitly infusing the teaching and assessment of generic skills into the programme is visible in the quality of the presentations and written work in the students' final portfolios.

In 2010, SP embarked on a strategic goal of "Providing Holistic Education" to its students. The CDIO skills (Standard 2) were adapted and the resulting set of six SP Graduate Attributes, consisting of Competence; Communication and Teamwork; Creativity, innovation and Enterprise; Ethics and Responsibility; Global Mindset; and Personal and Social Effectiveness were adopted institution wide and infused into all programmes. Detailed learning outcomes were developed for each of the graduate attributes (see Figure A2 for an example).

With the implementation of the Holistic Education initiative, the explicit teaching of the oral and written communication skills in DMAT were transferred to the new institutional courses, which were taught by experts in these areas. Effort was made to "twin" these courses with the appropriate DMAT courses. The lecturers teaching DMAT and the communication courses collaborated to create a common assignment, with one set of assessment criteria focused on communication, and another focused on music/audio related content (see Figure A1 for example). This has been quite successful.

Food Science and Technology

The Diploma in Food Science and Technology (DFST) is a three-year full-time programme. The aim of the programme is to develop food scientists and technologists who will be able to design innovative, safe, sustainable and quality food products and processes that excite the taste and imagination of today's adventurous consumers.

In 2013, the programme underwent a review, which resulted in a redesign of its curriculum and an update of its graduate attributes and learning experiences. The starting point of the curriculum review was the personas of its current and future students and the attributes of successful innovators in the industry. In addition to Communication, Teamwork and Time management skills, two key attributes of successful food innovators, Creativity, Innovation and Enterprise and Ethics and Responsibility (Figure A2), were identified and mapped into the curriculum and activities were designed to develop them (Figure 1).

In Year I, besides the foundational science courses like analytical, physical, organic and inorganic chemistry, the programme has an Introduction to Food Science course (Standard 4). In this course, the students discover the role of food science and technology in providing safe, sustainable and quality food products, from farm to consumers locally and globally. They examine various food materials and their technologies, such as beverage technology, cereal technology, egg and diary technology, meat and seafood technology, and fruit and vegetable technology. In Year 2, the students integrate their food science knowledge through projects and assignments that require them to transform raw materials and ingredients into consumer-focused end-products. They ideate food concepts (Conceive) and perform sensory evaluation (Design) (Standard 5, basic design-implement experience).

In the third year, the students develop processes and select food packaging that reduce food wastage and achieve sustainability of future food products. The students conceive new products using Design Thinking (Conceive); experiment with different raw materials, ingredients and appropriate processing methods to formulate and develop the product (Design); select the appropriate packaging and scaling up process of the product for shelf-life study (Implement); and finally pass the successful formulation to food companies for production (Operate). (Standard 5, advance design-implement experience). See example in Figure A3.

Effects of CDIO implementation at Singapore Polytechnic (SP)

The CDIO framework provided SP with a structured approach to enhance the design of our programs to better prepare students for professional work. In 2010, the CDIO syllabus were adapted into a set of six SP Graduate Attributes and applied to all programmes which included Business, Chemical and Life Sciences, Info-Communication and Media, and Design. The non-engineering programs were able to adapt and customise the Graduate Attributes for their own fields. Specific learning outcomes (standard 2) were written and activities identified. With the identification of the Graduate Attributes, the development of students' skills expanded from the initial skills of Thinking, Communication and Teamwork to include Creative, Innovation and Enterprise. The Design Thinking method was adopted to foster a user-centred approach to conceiving (C) and designing (D) new products and services. Using this method, all second-year students work in multidisciplinary teams to understand the communities' needs, draw insights from their interviews and observations, and co-create and prototype solutions. In summary, CDIO is applicable to both engineering and non-engineering programs and has become the foundational framework for other educational initiatives and developments in SP.

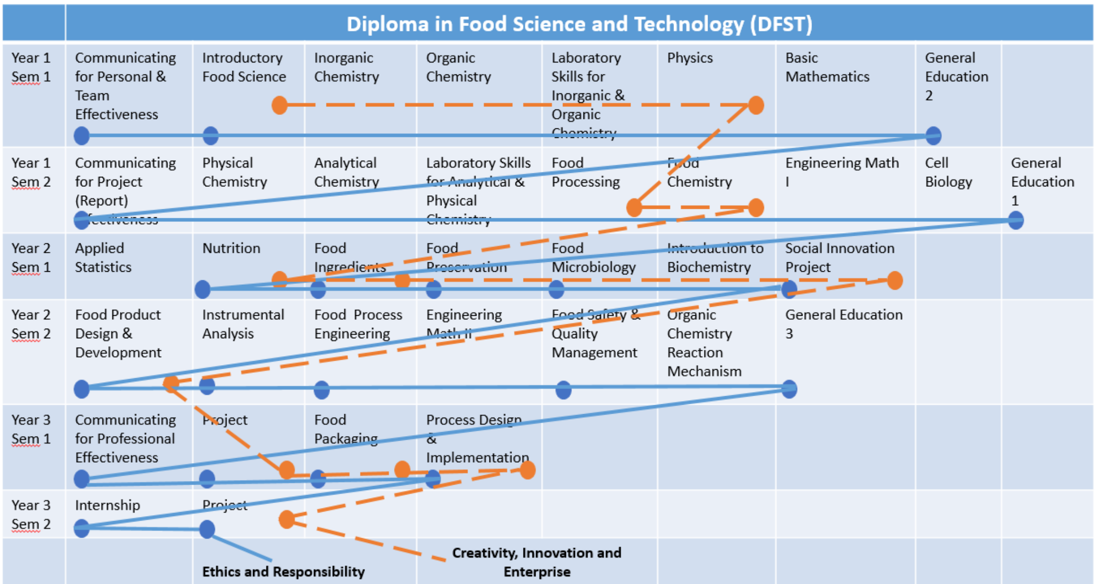

Figure 1: Map of Creativity, Innovation and Enterprise and Ethics and Responsibility in DFST

Turku University of Applied Science, Finland (TUAS)

Turku University of Applied Sciences (TUAS) is one of the biggest universities of applied sciences in Finland. TUAS' Faculty of Business, ICT and Chemical Engineering has bachelor and master programmes in engineering and in business administration. Since 2007, this faculty has used the CDIO approach for continuous education development.

TUAS had two main motives for applying CDIO: relevance to working life and quality of education. The starting point for a university of applied sciences is to have working life relevant education and to do applied research and development together with the industry and businesses. With its' CDIO initiative, TUAS aimed at strengthening this relevance and to better answer the challenges and problems recognized in our education. The challenges and improvement areas listed at the beginning were following:

- Improved introduction to -courses in every degree programme
- Increased use of active learning methods
- Improved assessment policies and methods
- Increased design-build experiences at earlier phase of studies
- Increased usage of our laboratories
- Decreased number of drop-outs
- More motivated students
- More motivated teachers.

Quality of education was another driver for the TUAS' CDIO membership. They saw that CDIO could provide them with coherent framework that approach education from different perspectives and provide tools to continuously evaluate and improve. They understood that CDIO is not a quality assurance tool itself, but it can surely influence education through the CDIO standards and syllabus.

In the beginning, the challenges and problems were quite similar in all TUAS' programmes. There were no proper introductory courses, use of active learning was scarce, laboratories and workspaces were underused to name few of the identified topics. Thus, TUAS decided at an early stage that the CDIO approach would be applied in all of the faculty's bachelor programmes - not only in engineering.

The CDIO implementation at TUAS has been strongly connected to faculty member's competence development. The key development areas have been planned for the whole faculty. The faculty development pathway has been described in a university report (Stenroos-Vuorio, 2012). The whole CDIO development started with a dedicated project that focused on introducing the faculty members to CDIO approach and to reflect TUAS' way of teaching and learning with CDIO (Kontio, 2007). At the end, main development areas were identified using the CDIO self-evaluation model (Standard 12). Based on the self-evaluation findings, TUAS wanted to enhance the use of active teaching and learning methods (Standard 8) and as a consequence provided a tailored training to its' faculty (Kontio, 2009a). At the same time, TUAS introduced industry periods for faculty members to strengthen faculty competences (Standard 9) in working life knowledge and product, process, and system building skills (Kontio, 2009b). Other faculty level initiatives have been competence based curriculum development (Standard 3) and assessment training (Standard 10). All the time development has been guided by the CDIO self-evaluation, which has been done six times on the programme level since 2007. The latest faculty level education development activities are common curriculum principles to all bachelor programs (Kontio, 2014 and Figure 2, right):

- The curriculum is based on relative large courses (15 credits or 25 % of a study year)
- The study year is divided in five periods (9 weeks, 7 weeks, 9 weeks, 7 weeks and 7 weeks)
- All programmes have introduction to – courses in the first semester
- There is a multi-disciplinary innovation project (15 credits) in the third year of studies,
- There are elective modules in the beginning of second and third year (15 credits each).

These principles confirm the role of introduction to –courses (Standard 4) and design-implement experiences in the curriculum (Standard 5). The innovation project (15 ECTS) is implemented in multidisciplinary teams of 6-8 mainly 3rd year students. During the course students develop a prototype solution to a problem or need of a real client. The innovation project is described in more detail in Kulmala et al. (2014) and additional information is provided on the course website (http://capstone.dc.turkuamk.fi/). With elective modules, TUAS is aiming for T model experts (Figure 2, left) that are required in the future working life.

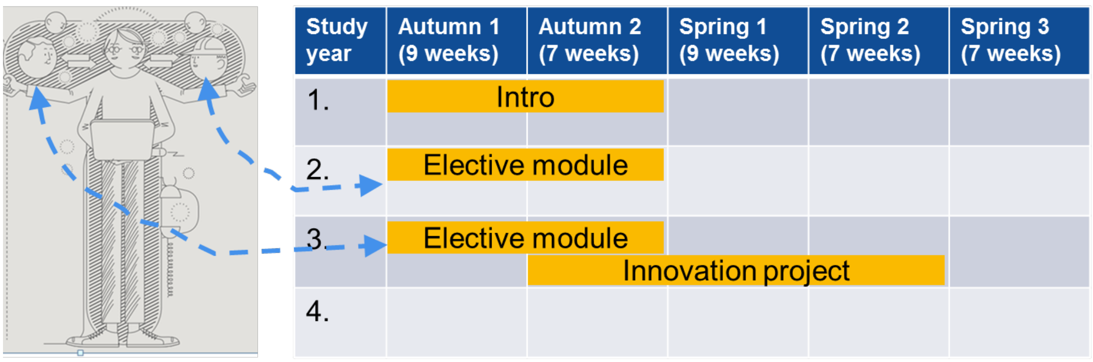

Figure 2. General structure of the curriculum at TUAS

Business and Library and Information Services programmes

The TUAS degree programme in *Business* aims to train the student to a business specialist with focus on one of the following: business development, entrepreneurship, or accounting. The programme emphasizes working with innovative attitude within and across business and modern ICT. The degree programme in *Library and Information Services* educates professionals who understand information behaviours and are prepared to guide information literacy skills. Students will graduate in profession where it is essential to be able to navigate in the world of information, collections and records despite the existing format. They will achieve the skills and knowledge in information organization and retrieval.

The degree programmes in Business and in Library and information services have followed the faculty level development and they have participated all the actions mentioned above. Both programmes have an introductory course at the beginning of their studies. In Business programme it is called nowadays Business start. This Business start module (15 credits) provides basics of business in a form of Practise enterprise. A practise enterprise is a simulated start-up company formed by the students. There is a real enterprise working in the background of the simulated practise enterprise to support business planning and to provide real-life information for start-up. Practise enterprises do business with each other in a global network of practise enterprises. Both programmes have elements that strongly take advantage of active learning. In core of the learning are real assignments and projects from our partners. These programmes have put a lot of effort in creating workspaces that support and encourage hands-on learning in business and library and information services. This is actually a good example of interpreting the CDIO approach outside engineering. Although CDIO Standard 6 is called Engineering workspaces it is possible to use it as a vehicle to improve the learning environment in a non-engineering programmes. To summarize: the non-engineering programmes of TUAS following CDIO have interpreted CDIO approach to fit into their field.

Effects at TUAS

TUAS has found out that their approach to implementing CDIO to all our programmes whether they are engineering or not has resulted in deeper multidisciplinary collaboration between both faculty and students. The innovation project and the elective modules are good examples where engineering and non-engineering students study and work together during their studies. In addition, TUAS pedagogical development projects have also become multidisciplinary were teachers in different disciplines share experiences and work together for better learning and teaching. The understanding of each programme's special challenges and problems has grown. Sometimes CDIO has been questioned as suitable solution/framework for non-engineering programmes, but it has been easy to raise the level of discussion above the engineering specific issues and focus on education development in more general context. At the beginning there was a lot of discussion on the costs of doing teaching and learning in CDIO way. First, the CDIO-like courses seemed to be more expensive than traditional ones, but once the teachers learned the new pedagogical methods and understood CDIO better also this discussion has calmed down. In summary, the non-engineering programmes at TUAS have successfully used and implemented CDIO by interpreting and adapting CDIO into their own field.

Vietnam National University-Ho Chi Minh City, Vietnam (VNU-HCM)

Vietnam's increased integration into the global economy, through its membership in WTO (2007) and in ASEAN Economic Community (2015), has placed greater demand on Vietnam's higher education institutions (HEIs) to train a skilled labor force for societal needs. This demand entails improving education programmes, and developing quality assurance and accreditation processes (MOET, 2005). At national and university levels, a number of policy measures and initiatives have been implemented, such as Institutional Evaluation Standards; the Advanced Curricula; Programme evaluation by ASEAN University Network-Quality Assurance Criteria (AUN-QA); and ABET Accreditation. While the advanced curricula and the evaluation or accreditation criteria have provided models and specific requirements that a programme in specific discipline has to satisfy, Vietnam's HEIs still need a more comprehensive educational methodology or framework to prepare for their programme evaluation, accreditation, and continuous improvement (Phan et al., 2010) (Nguyen et al., 2013).

VNU-HCM found that the CDIO approach, an idea and methodology for engineering education reform, with its CDIO Syllabus and a set of 12 CDIO Standards, provides answers to the "what" and "how" questions in a systematic and un-prescriptive way, making it viable for undergraduate programmes in Vietnam to adapt CDIO according to their unique needs and conditions (Phan et al., 2010). For its strengths, the CDIO approach has been adopted at VNU-HCM as the basis for a model framework for curriculum reform (Phan et al., 2010, & 2011).

CDIO adaptation to non-engineering programmes at VNU-HCM

With the goal for developing the model framework for education programme reform based on the CDIO approach, five programmes (at University of Technology, and University of Science) including non-engineering where in 2010 selected as the pilots to implement CDIO systematically, providing students with the knowledge, skills, and attitudes desired by programme stakeholders. As a consequence, adapted and generalized curricular frameworks for non-engineering programmes have been developed. These frameworks include:

- The discipline-customized CDIO Syllabi, so-called Programme Learning Outcomes (PLOs) Syllabi (Doan et al., 2012a, & 2012b);
- The detailed framework and templates for integrated curriculum development complied with principles of the CDIO Standards 1-3, 7 and 11, so-called the CDIO-Based Curricular Framework and Guidelines for OBE Implementation (Doan & Nguyen, 2014a) (Outcomes-Based CF); and
- The Generalized CDIO Standards (Doan et al., 2014c).

These PLOs Syllabi, Generalized CDIO Standards, and Outcomes-Based CF have been adopted as Guidelines for CDIO Adaptation, and Guidelines for Outcomes-Based Curriculum Development (Doan & Nguyen, 2014b). They are now being used widely and have been parts of the Faculty Development Programme at VNU-HCM (Doan et al., 2014b).

After 3 years of successful CDIO application to the first five programmes, CDIO has been expanded to 15 additional programmes. Among these programmes, Chemistry (at University of Science) and International Business (at University of Economics and Law) have adopted and adapted CDIO to prepare for their AUN-QA evaluation and continuous improvement (Nguyen et al., 2015b) (Nguyen et al., 2015a).

CDIO adaptation to the Chemistry programme, 2013-2015

The CDIO adaptation to the Chemistry programme and its results are summarized in Table 3. The PLOs Syllabus for applied science disciplines (Doan et al., 2012a) was introduced to the programme. The general professional competence "*conceiving, designing, implementing, and operating or verifying"* (CDIO/V), and the common objects of professional practice "*problem, experiment, program, process, and system*" were defined into "*conceiving, designing, implementing, and operating or evaluating chemical products and processes*" (CDIO/E) (Nguyen et al., 2015b). Though it was recommended that PLOs should be designed according to the four sections of the PLOs Syllabus, the PLOs have been constructed by merging of the personal skills and interpersonal skills. As many university's programmes adapt CDIO, all programmes should unify the structure of their PLOs as directed by the generalized CDIO Standard 2 (see Table 1), in order to make their PLOs recognized by each other, and to facilitate course development.

Significant changes have been made to the curriculum design and implementation. These changes include integrated curriculum, introduction course, and integrated learning experiences. To achieve integrated learning experiences, the Outcomes-Based CF's templates for course design and implementation complied with constructive alignment principles were implemented for all programme's courses. The Introduction to Chemistry course shown in Figure A4 to Figure A6 gives an example of a CDIO-based course. As specified by CDIO Standard 7, the course goals should include goals for disciplinary knowledge as well as generic skills, and must be linked to the related PLOs topics at x.x.x-level (see Figure A4). Teaching and learning activities are designed to align with the learning outcomes (see Figure A5). The spiral curriculum approach is utilized to structure the teaching and learning activities in a way that they build on each other in an ever more complex and sophisticated way from the beginning to the end of the sequence of class sessions or periods during a term. An effective way to organize these activities is to determine whether the material to be learned is being introduced (I) to the learner, is being thoroughly taught (T) to the learner, or is intended to be used (U) by the learner. The course plan aligns the course learning outcomes, teaching and learning activities, and assessment (see Figure A6). Assessment activities are developed to align with the learning outcomes and teaching activities (see Figure A5).

Table 3. CDIO Adaptation to the Chemistry programme at VNU-HCM

CDIO Adaptation to the Chemistry programme and results	
Std1	Programme educational objectives statement reformulated into more specific one, that describes adopting of profession's context of practice as the context for education, and approved by University's Board of Education: *"Chemistry, an experimental discipline that includes organic, inorganic, analytical, and physical chemistry. The Chemistry program aims to provide students with comprehensive knowledge, skills, and attitudes required to conceive, design, implement and operate or evaluate (CDIO/E) such chemical products and processes…"* (Nguyen et al., 2015b)
Std2	Specific, detailed PLOs added, reviewed, and validated by faculty, students, alumni, and representatives of employers; and approved by University's Board of Education. *"(1) Disciplinary knowledge and scientific reasoning, (2) professional skills and attributes, (3) personal skills and attributes, and interpersonal skills, and (4) competence in CDIO/E chemical product and process in the research, enterprise, societal, and environmental contexts"* (Nguyen et al., 2015b)
Std3	The programme plan renewed with restructuring of Math and English courses; adding of courses in core chemistry fundamental knowledge, and internship; and re-arranging of courses in advanced chemistry fundamental knowledge. The programme ideas, skill development routes, and curriculum design matrix added

Std4	Introduction to Chemistry added as a mandatory course. The course delivered since 2014, and reviewed each year. *"Introduction to chemical product lifecycle development and deployment; the tasks and responsibilities of chemists, and the use of disciplinary knowledge, methods and tools in executing those tasks; and the impact of chemistry on society. The course provides basic training on personal and interpersonal knowledge, skills, and attitudes, problem solving and design skills through the course project leading to a design of simple experiment in the general chemistry laboratory, and project report and presentation"* (Nguyen et al., 2015b)
Std5	Design-implement experiences redesigned and integrated into four mandatory courses and co-curricular activities to cultivate design and interpersonal skills. The courses delivered since 2014. *Introduction to Chemistry; Advanced design course; Internship; and Final project* (Nguyen et al., 2015b)
Std6	Laboratories for chemical practice re-arranged supporting experiencing design and applying skills.
Std7 Std8 Std11	All courses redesigned complying with constructive alignment, and providing integrated learning experiences, and active and experiential learning. The courses delivered since 2014. Learning assessment uses a variety of methods matched appropriately to learning outcomes.
Std9	Training courses on enhancement of faculty competence in communication and teamwork skills, and project management, for junior teachers, added and conducted in 2013.
Std10	Training courses on enhancement of faculty teaching competence (Std7, 8, and 11) for all faculty members, and support for faculty participation in faculty development programmes, added and conducted for 2013-2015. Majority of faculty competent in course design and instruction with constructive alignment. Teachers required to provide self-report on course teaching, learning, and assessment.
Std12	Instructor reflections, and follow-up studies with alumni and employers to be regular course evaluation activities, since 2015.

CDIO adaptation to the International Business programme, 2013-2015

The CDIO adaptation to the International Business programme and its results are summarized in Table. 4. The PLOs Syllabus for Business disciplines (Doan et al., 2012a) was introduced to the programme. The general professional competence "*conceiving, designing, implementing, and evaluating"* (CDIE), and the common objects of professional practice "*problem, plan, project, model, procedure*" were defined into "*conceiving, designing, evaluating, and improving business projects*" (CDEI) (Nguyen et al., 2015a). The PLOs have been designed according to the four sections of the PLOs Syllabus.

Table 4. CDIO Adaptation to the International Business Programme at VNU-HCM

CDIO Adaptation to the International Business programme and results	
Std1	Programme educational objectives statement reformulated into more specific one, that describes adopting of profession's context of practice as the context for education, and approved by University's Board of Education. "…*The International Business program aims to provide students with comprehensive knowledge, skills, and attitudes required to conceive, design, evaluate and improve (CDEI) business projects in international context*…" (Nguyen et al., 2015a)
Std2	PLOs constructed in form of four sections of the PLOs Syllabus at 4-level of detail added, reviewed and validated by faculty, students, alumni, and representatives of employers; and approved by University's Board of Education. *"(1) Disciplinary knowledge and reasoning, (2) personal and professional skills and attributes, (3) interpersonal skills, and (4) competence in CDEI business projects in the enterprise, societal, and environmental contexts"* (Nguyen et al., 2015a)
Std3	The programme plan renewed; the programme ideas, skill development routes, and curriculum design matrix added
Std4	Introduction to International Business added as a mandatory course. The course delivered since 2014, and reviewed each year.

	"Introduction of the professions, ethics, and the use of disciplinary knowledge; training of problem solving, project management and design, and teamwork and communication skills through a project leading to a business concept and plan, and report" (Nguyen et al., 2015a)
Std5	Design-evaluate experiences redesigned and integrated into five mandatory courses and co-curricular activities to cultivate design and interpersonal skills. The courses delivered since 2014. *Introduction to International Business; International Business 1&2; Internship; and Final project* (Nguyen et al., 2015a)
Std6	New CDEI workspaces and Centre for Economics Study built in order to support and encourage experiencing CDEI business projects
Std7 Std8 Std11	Same as for the Chemistry programme (see Table 3)
Std9	Training courses on enhancement of faculty competence in personal, communication, and teamwork skills, and project management, added and conducted.
Std10	Same as for the Chemistry programme (see Table 3)
Std12	Instructor reflections, and follow-up studies with alumni and employers to be regular course evaluation activities, since 2014.

Effects of the CDIO implementation in Chemistry and International Business programmes

Three years into implementing CDIO Standards, the curricula have been thoroughly reformed. Curriculum components added, and renewed, especially for the first time, include: specific and detailed generic skills and professional competences validated by programme stakeholders; integrated curricula; relevant introductory courses; and course syllabi complying with constructive alignment. The greatest achievement in implementing CDIO is that majority of faculty are competent in providing integrated learning experiences, active and experiential learning, and learning assessment that make themselves more innovative in their instruction in order to improve student learning outcomes. These changes supported International Business programme to be accredited by the AUN-QA evaluation in 2015 with positive reviews for curriculum design, teaching facilities, teaching and learning strategy, and student assessment (Nguyen, et al., 2015a); supported Chemistry programme underwent VNU-HCM's internal evaluation by AUN-QA criteria in 2015 (Nguyen et al., 2015b); and both for their continuous improvement.

DISCUSSION

Let us now compare the studied implementations of CDIO in non-engineering programmes, within this group, and with CDIO experiences from engineering programmes as reported by Malmqvist *et al*. (2015). Table 5 summarises motives, modifications to the CDIO framework, effects and challenges.

Amongst motives, we notice aims to better connect to working life practices, to improve educational quality, to improve design & innovation skills and to improve generic skills. We can notice that these are four out of the five most frequently mentioned motives for applying CDIO in engineering programmes (Malmqvist et al., 2015). It would seem reasonable to claim that these non-engineering programmes are applying CDIO for the same reasons as engineering programmes. There is some variation, though. In Vietnam, the educational system wanted to establish its international credentials and comparability, motivating a strong interest in the use of CDIO to prepare for an accreditation. In Singapore, design and collaboration skills were brought forward.

All of the programmes have made modifications to the CDIO framework to fit the context. However, it is shown in the paper that these modifications are minor. Also engineering programmes assessed that it was easy to customize the CDIO framework to fit their (engineering) context (Malmqvist et al., 2015). It would seem that the CDIO framework can be customized to different contexts, while not being over-generalized, i.e. so abstract that it no longer provides concrete support and guidance for programme development.

The (self-reported) positive effects of CDIO implementation closely mirrors the motives for applying CDIO, i.e. it seems that this group of programmes have been successful in their implementation projects: the students have improved their skills in the desired direction, accreditation has been achieved and so on.

As in many educational development projects, it is noted that faculty resistance to change is a main challenge. In these cases, the inclusion of generic skills (teamwork, communication, ethics etc.) in regular courses seems to be a common concern amongst faculty who are used to teaching only their subject matter. However, integrated learning is a key characteristic of CDIO. The solutions to manage this challenge applied by the studied programmes include both faculty training in the teaching of generic skills in the context of their subject matter course and inclusion of generic skills specialists in teacher teams for courses. The Singapore programmes show that you may start with the faculty training approach, but then evolve to a format where regular faculty and communication (etc.) specialists co-teach in courses. In any case, it is clear that faculty training is an important element of any CDIO implementation project.

Common for the studied programmes is also that CDIO implementation has been done across the whole university and university system (VNM-HCM case) including both engineering and non-engineering programmes. This should mean that the university has the competence in pedagogical development required to carry out a CDIO implementation. This has probably been a helpful factor in these cases, and it might be that non-engineering programmes who lack this support may find it harder to translate CDIO to their context and thus to implement CDIO.

Table 5. CDIO experiences in non-engineering programmes

Aspect		Programme / University				
	Music & audio technology	*Food science & technology*	*Business*	*Library & information services*	*Chemistry*	*International business*
Targeted professional role(s)	Professionals who can create music and audio content for the media industry	Food scientists and technologists	- Entre-preneur - Accountant - Business professional	- Librarian - Information service assistant/ expert	- Research chemist - Analytical chemist	- Import/ export agent - Foreign sales rep - Intern management consultant
Motive	- Need to systematically develop generic skills. - Need to develop creative skills and ethical attitudes	- Need to develop creative skills and ethical attitudes	- Strengthen relevance to working life - Improve quality of education		- Strengthen relevance to working life - Prepare for evaluation by AUN-QA/ accreditation by ABET criteria	

Modifications to CDIO framework	CDIO syllabus 3.1 (Teamwork), 3.2 (Communications), 2.4 (Attitudes, Thoughts and Learning) and 4.2 (Enterprise and Business context) were adapted and customised at the x.x.x level.	CDIO syllabus 2.4 (Attitudes, Thoughts & Learning), 2.5 (Ethics, Equity & other Resp) and 4.1 (External, societal and Environmental context) were adapted and customised at the x.x.x level.	Engineering specific parts have been adapted and transformed to business context	Engineering specific parts have been adapted and transformed to programme context	Engineering domains have been transformed into generalized ones to make them more applicable to any programme: - CDIO Syllabus has been transformed into discipline-customized CDIO Syllabi - CDIO Standards have been transformed into Generalized CDIO Standards
Benefits	- The teaching and utilisation of the skills were made explicit. - Improvements were observed in the quality of students' presentations and written work.	- Integrated critical & creative thinking and ethics & responsibilities - Students have a framework to guide the concept-ualisation, design and development of innovative food products.	- Improved relevance to working life - Programme development has been better managed - Multi-disciplinary collaboration amongst staff and students		- Programme has been reformed systematically - Improved faculty pedagogical competence - Programme has successful in its evaluation, and in continuous improvement
Limitations/ drawbacks	Relies on staff to effectively learn to teach soft skills	Due to the nature of the different projects students do, not all of them go through the full CDIO process	Syllabus – not for business context	Syllabus – not for library and information science context	Unidentified
Challenges	Some staff needed a lot of convincing of the value of infusing generic skills into their teaching. Finding appropriate activities in the courses to infuse generic skills	Buying in from staff to incorporate these skills into the modules.	Some resistance at the beginning – how can an engineering education framework help us? How to adapt engineering focused standards to business context?		Train faculty to be more accountable and innovative in their instruction in order to improve student-learning outcomes in large classes with limited number of teaching assistants.

CONCLUSIONS

In this paper, we have shown that the CDIO approach can be applied to non-engineering disciplines given that a general description of CDIO is applied, a professional context of the education can be identified, and that the CDIO standards are translated to the context in question. Rich descriptions of six non-engineering programmes that have implemented CDIO support and exemplify this claim. We further demonstrate that the CDIO development tools are helpful also when designing non-engineering (and non-professional) programmes.

The motives for implementing CDIO amongst the studied non-engineering programmes include aims to improving teaching of design skills and of generic skills, to strengthen the connections to the working life, and to enhance educational quality, both in terms of continuous improvement, and in terms of meeting international accreditation requirements. A further motive to select CDIO as an approach for educational development amongst these programmes is that they are offered by universities that have CDIO as a strategy for all their programmes.

The obtained benefits are very well aligned with the motives and it can thus be argued that the programmes' CDIO implementations have been successful.

Overcoming faculty resistance to teaching skills outside of their subject specialty was the major challenge that the programmes experienced when implementing CDIO. Faculty training and co-teaching with generic skills specialists was applied to address these challenges.

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BIOGRAPHICAL INFORMATION

Johan Malmqvist is a Professor in Product Development and Dean of Education at Chalmers University of Technology, Göteborg, Sweden. His current research focuses on information management in the product development process (PLM) and on curriculum development methodology.

Helene Leong-Wee Kwee Huay is the Director of the Department of Educational Development at Singapore Polytechnic. Her current focus is on the use of technology in education, enhancing students' intrinsic motivation, and the pedagogy for professional formation and identity.

Juha Kontio is the Dean of the Faculty of Business, ICT and Chemical Engineering in Turku University of Applied Sciences. He is a Doctor of Sciences in Economics and Business Administration. His current research interest is in higher education related topics. He is a co-leader of the European CDIO region.

Trinh Doan Thi Minh is an Associate Professor in Mechanical Engineering, and Education Development Project Manager at Vietnam National University-Ho Chi Minh City (VNU-HCM), Vietnam, including the CDIO Implementation Project. Her current research focuses on geometric modelling for CAM/CAM, and curriculum development in higher education.

Corresponding author

Johan Malmqvist
Chalmers University of Technology
Department of Product and Production Development
SE-41296 Gothenburg, Sweden
+46 70 3088600
johan.malmqvist@chalmers.se

Assignment: Cycle Based Composition
Overview: This exercise is designed to focus your awareness on using the basic music materials (timbre, texture, rhythm, melody and harmony) to create a large(ish) scale musical form.
Objectives:
Through this assignment, you should be able to:

- Understand the role of repetition to create cohesion.
- Create a piece, making use of the software synthesizers available in Logic.
- Use the approach of "design a **performance system**, then realize a piece".

Guidelines

- Your performance system should consist of many small repeating patterns.
- The piece should have 4 contrasting sections and should last between 5 and 10 minutes.
- There should be other musical elements, such as bass parts, melodies etc. that are not MIDI loops.
- The overall form should be shaped via by the automation system. Some cycles should be created with the Ultrabeat step time sequencer and Cycle MIDI recording.

Report:
You are to submit a write-up with a minimum of 200 words to describe the process that you used to create the piece. This write up should be structured around the metacognition model discussed in class. This means there should be sections detailing:

- Generating Possibilities: how you created the cyclic midi regions.
- Analysis: what attributes of the midi loop you used decide how it is to be used?
- Comparison and contrast: how are the regions similar/different?
- Inference and interpretation: do any of the regions suggest/imply particular usage?
- Evaluation: how was the final choice of presentation of the material made?

Figure A1: A DMAT assignment that incorporates written communication and thinking skills

1 Creativity, Innovation and Enterprise (CDIO syllabus 2.4, 4.2)

1.1 Apply critical and creative thinking skills in problem solving (CDIO syllabus 2.4.3, 2.4.4, 2.4.5)

- 1.1.1 Use a range of critical thinking skills (e.g., analysis, comparison and contrast, inference and interpretation, and evaluation)
- 1.1.2 Use the creative thinking process (e.g., generating possibilities, incubation, illumination)
- 1.1.3 Identify barriers to effective thinking (e.g., traits, dispositions, working memory, perception, lack of information)
- 1.1.4 Identify contradictory perspectives and underlying assumptions
- 1.1.5 Use metacognition in monitoring the quality of personal thinking

1.2 Able to develop products, processes and services, in a business or entrepreneurial context (CDIO syllabus 4.2.3)

- 1.2.1 Recognize entrepreneurial opportunities to develop products, processes and/or services
- 1.2.2 Use a range of critical and creative thinking approaches (e.g., Design Thinking, Systems Thinking) and tools (e.g., Brainstorming, Mindmapping)
- 1.2.3 Reframe and take a range of different perspectives
- 1.2.4 Identify the business focus in the design of products, processes, or services

Figure A2: Example of SP Graduate Attributes and its Accompanying Learning Outcomes

Food Packaging Course
Design Project

You are employed as a Food Technologist at Happy Family Food Pte Ltd (same company as Process Design & Implementation course). As part of your training, you are required to develop the packaging of the assigned food product to enhance their freshness and shelf life.
Food product assigned: ______________________

PART 1 RESEARCH ON PACKAGING (CONCEIVE)

1. Conduct a literature review on the issues/ problems encountered and technologies available to package your product.
2. Go shopping in supermarket and/ or wet market to research on how the product is commonly packaged.

PART 2 EXPERIMENTAL DESIGN (DESIGN)

1. Research on how to improve the shelf life of your product by means of packaging technology.
2. Design the experiments to evaluate the effectiveness of the packaging technique(s) or material(s) on the shelf life of the product. Decide on the shelf life of your product.
3. Decide on the storage conditions i.e. temperature and relative humidity.
4. Present your proposal (including packaging materials, techniques, sampling plan).
5. Fine-tune your proposal and upload to Blackboard by 26 Jun 2015.

PART 3 SAMPLE PREPARATION AND SHELF LIFE EVALUATION (IMPLEMENT)

1. Prepare samples of the product (including control).
2. Carry out the experiment based on your final proposal. You are not allowed to deviate from your experimental design.
3. Collate your data and analyse your results.

PART 4 PACKAGING DESIGN

1. Based on your results, select the technique(s) or material(s) to be used to package the product.
2. Prepare a prototype of the packaging (including the label).
3. Present a 15 minute presentation*.
   * Combined presentation for Food Packaging module and Process Design & Implementation courses.

Figure A3. Food packaging design project description

Introduction to Chemistry

Course Description: Introduction to chemical product lifecycle development and deployment; the tasks and responsibilities of chemists, and the use of disciplinary knowledge, methods and tools in executing those tasks; and the impact of chemistry on society. The course provides basic training on personal and interpersonal knowledge, skills, and attitudes, problem solving and design skills through the course project leading to a design of simple experiment in the general chemistry laboratory, and project report and presentation.

Course Goals (Gx.)

Gx.	Related LOs topics	Required level of competence	Description
G1.	4.1.1, 4.1.2, 2.2.2	2	*Accept* the chemical product lifecycle development and deployment, the tasks and responsibilities of chemists, and the impact of chemistry on society
G2.	2.2.2, 2.4.1 - 2.4.7	2	*Accept* the essential one's attitudes, thoughts and learning for effective learning
G3.	4.3.4	2	*Understand* principles of project management, and *apply* to the course project
G4.	4.3.1, 4.3.2 4.4.1 - 4.4.3 1.1.x - 1.3.x	2	*Understand* the chemical product design process and approaches, and utilization of knowledge in design, and *apply* to an experiment design in the course project
G5.	3.1.1 - 3.1.4	2	*Understand* principles of teamwork, and *apply* to the course project
G6.	2.1.1, 2.1.2, 2.1.5, 4.4.3	2	*Understand* concepts of problem solving, and *apply* to an experiment design in the course project
G7.	3.2.1 - 3.2.4, 3.2.6	2	*Apply* written and electronic communication, and oral presentation
G8.	2.5.1 - 2.5.4	2	*Accept* the ethics, equity and other responsibilities of chemists

Figure A4. Introduction to Chemistry's Course Description and Goals

Introduction to Chemistry

Course Learning Outcomes (CLOs), Teaching, and Assessment

A (individual or group assignment), **E** (exam), **P** (project work individual or in team)

CLOs	Description	Teach. levels	Assessment
G1.1	*Describe* the chemical product lifecycle development and deployment, the professions, the tasks and responsibilities of chemists, and the impact of chemistry on society	T	A1. group assignment A2. group presentation
G1.2	*Select* and *describe* one's own intended future careers	U	A3. individual essay
G2.1	*Describe* the essential personal skills and attitudes for effective learning	T	A4. group assignment A5. group presentation
G2.2	*Define* one's own learning methods for the Introduction to Chemistry course; and *describe* one's own learning goals and plans for the 1st semester	T, U	A6. individual assignment
G3.1	*Describe* tasks of project management, and the functions of OPPM™ (One Page Project Manager)	T	E1. midterm exam
G3.2	*Explain* the course project plan created by using OPPM	U	P1. course project plan
G4.1	*Describe* the chemical product design process, and design process phasing and approaches	T	E2. midterm exam
G4.2	*Define* the experiment design process and approaches used in the course project	T, U	P2. design process and approaches
G4.3	*List* the courses teaching underlying mathematics and sciences, and chemistry fundamentals in the Chemistry programme	I	P3. utilization of knowledge in design
G4.4	*Explain* utilization of knowledge in experiment design of the course project	T, U	
G5.1	*Describe* team roles and responsibilities for the course project	T, U	P4. team formulation
G5.2	*Explain* the course project schedule created by using OPPM	T, U	P5. team operation
G6.1	*Describe* problem solving methods	T	A7. group assignment
G6.2	*Select and explain* using problem solving methods for the experiment design	T, U	P6. problem solving
G7.1	*Demonstrate* preparing the course project poster with coherence and flow	T, U	P7. written communication
G7.2	*Demonstrate* preparing the course project electronic presentation with supporting media, and answering questions effectively	T, U	P8. electronic communication & oral presentation
G8.1	*Describe* the basic professional ethical standards and principles of chemists	T	A8. group assignment
G8.2	*Define* one's professional skills and attitudes to be developed	U	A9. individual essay

Figure A5. Introduction to Chemistry's Course Learning Outcomes, Teaching, and Assessment

Introduction to Chemistry

Lesson Plan

T (Teacher), S (Student in class), H (Homework)

Session	Contents	CLOs	T&L activities	Ass.
1.	1. Introduction to chemistry	G1.1 G1.2	T: introduces the course, gives lecture, and guides students through information research; S: discuss topics and do group assignment; H: prepare group presentation	A1
2.			S: deliver group presentation; T: gives lecture; H: do individual assignment	A2 A3
3.	2. Personal skills and attitudes for effective learning	G2.1 G2.2	T: gives lecture; S: discuss topics and do group assignment H: prepare group presentation	A4
4.			S: deliver group presentation; T: gives lecture; H: do individual assignment	A5 A6
5	3. Project management	G3.1 G3.2	T: gives lecture and assignment to project teams, and guides students through project planning using OPPM; S, H: work in team to create the course project plan using OPPM	
6	4. Design in chemistry	G4.1 G4.2	T: gives lecture, and guides students through experiment design process and approaches; S, H: work in team to define experiment design process and approaches used in the course project	
7	5. Chemistry fundamentals	G4.3 G4.4	T: introduces underlying mathematics and sciences, and chemistry fundamentals, and utilization of knowledge in design; S: discuss topics; H: work in team to do the course project	
8	**Midterm exam**		Written exam Midterm project defence	E1-E2 P1-P3
9	6. Teamwork	G5.1 G5.2	T: gives lecture, and guides students through team formation and operation S, H: work in team to formulate team working rules and contract, and schedule project using OPPM	
10	7. Problem solving	G6.1 G6.2	T: gives lecture, and guides students through selection of problem solving methods for the experiment design; S: discuss topics and do group assignment; H: work in team to design an experiment in the general chemistry laboratory	A7
11	8. Communication	G7.1 G7.2	T: gives lecture, and guides students through making the course project poster and Powerpoint presentation; S, H: work in team to accomplish the poster and ppt presentation.	
12	9. Ethics, equity and other responsibilities	G8.1 G8.2	T: gives lecture; S: discuss topics and do group assignment; H: do individual assignment	A8, A9
13	**Final exam**		Final project defence	P4-P8

Figure A6. Introduction to Chemistry’s Lesson Plan