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Michael E. Auer
Kwang-Sun Kim *Editors*

Engineering Education for a Smart Society

World Engineering Education Forum & Global Engineering Deans Council 2016

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Editors

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Foreword

WEEF & GEDC 2016 Seoul was the fourth biennial joint conference of the International Federation of Engineering Education Societies (IFEES) and the Global Engineering Deans Council (GEDC). Every two years, IFEES and GEDC work together with local engineering and engineering dean societies to bring engineering education stakeholders to one place to lead the global conversation on topics ranging from the role of industry and government in engineering education, diversity in engineering education, engineering education in the face of globalization, and the role of technology in engineering education.

IFEES is proud to be leading the effort in connecting the world's engineering education societies and leveraging our members' collective strengths in order to improve engineering education worldwide. IFEES members represent a diversity not only in cultures, but in engineering education interests, from quality assurance to engineering education and from pedagogy to the role of technology in the classroom.

GEDC's vision is to enhance the capabilities of engineering deans to transform schools in support of societies in a global economy. Its mission is to serve as a global network of engineering deans, and to leverage on the collective strengths, for the advancement of engineering education and research.

This year, the Forum was organized by the Korea Society for Engineering Education (KSEE) and the Korea Engineering Deans Council (KEDC). Meetings took place from November 6–10, 2016, at the COEX, Seoul, Korea. The theme of the 2016 Forum was Engineering Education for Smart Society.

Once again, the Forum invited several outstanding leaders from around the world to share their experiences. We were fortunate to have the following to be our main plenary speakers:

- Hiroshi Komiyama, Former president, University of Tokyo, Japan
- Ohjoon Kwon, CEO, POSCO, Korea
- C.D. Mote, Jr., President, National Academy of Engineering, USA

Is Smart Society the Goal?

Imagine the daily routine of Ms. Wang, the average woman working in any major metropolis in the modern world. A smart speaker awakes Ms. Wang at 5:15 A.M. and immediately turns on the TV in the bathroom, which is set to the news so that she can browse headlines as he brushes his teeth. She sits down to breakfast, spoon in one hand and mobile phone in the other, checking her schedule for the day. She has a call with a colleague who lives five time zones away, and decides to take the call from home before going into the office, as she has been advised by her smart speaker that traffic on her work commute is heavier than usual today. On the way to the office, she checks work message on her phone. For lunch, she and her coworkers take a self-driving taxi to a restaurant that was highly rated on a crowd-sourced review site. At the office, all her work is done on the screen. After a long day, she comes home to the sound of her favorite music, which her smart speakers know to play upon her arrival.

In a society that values speed, efficiency, and convenience, this is a picture of near-perfection. Undoubtedly, technology has afforded Ms. Wang (and much of the world) many conveniences throughout her average day. And yet, science is showing that there are veritable social pitfalls to the overexposure of technology in everyday life: diminished human relations, distraction, loneliness, impatience, inability to cope with uncertainty, privacy issues, and information overload. Reflecting on history, there is a pattern of one hand welcoming the wonders of technology, while the other hand pushes aside the consequences. Advances in transportation, air pollution; mass production, landfills; automation, decrease in value of human workers.

If engineers help to create the technology that enables certain social ills, what responsibility do they have to prevent technologies from being abused? And what responsibility do we, engineering educators, have when considering the message that we send to future generation of engineers?

These are the types of questions that motivate us to take a critical approach to engineering and engineering education. This book brings together the best of the papers from WEEF GEDC 2016, giving an in-depth look at the various facets of engineering education.

Relevance of Engineering Education *Section Editor: Susan Oh & Uriel Cukierman*
Excellence in Engineering Education *Section Editor: Peter Kilpatrick*
Access to Engineering Education *Section Editor: Lueny Morell*
Equity and Diversity in Engineering Education *Section Editor: Khairiyah Mohd Yusof*

My special thanks go to the conference's review committee who reviewed over 300 papers. We were able to accept only 135 submissions for presentation.

My thanks to everyone who came to Seoul to be a part of our larger conversation on engineering education. We look forward to seeing everyone in November for our WEEF 2017 Kuala Lumpur.

Hans J. Hoyer

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Relevance of Engineering Education

Introduction for Section #1 "Relevance of Engineering Education"

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Needless to say, that in our hyperconnected and challenging world, Engineering is a very relevant profession and, accordingly, Engineering Education is a very relevant issue. According to all available statistics, the demand for well-trained engineers over exceeds the current supply, so there is a certain "bottleneck" in this pipeline. Moreover, since several decades ago and in different regions of the world, basic questions about the relevance of engineering education have been raised. The problems include a lack of practical skills in modern engineering training, the lack of relevance for industry of the science being taught, and the kind of analytical qualifications being awarded in engineering education compared with vision of engineers as creative designers and innovators of future technologies[1]. As these problems have not been properly addressed and the demand for well-trained engineers has increased steadily, the situation in today's smart society is even more challenging.

The International Federation of Engineering Education Societies (IFEES) has been trying to help the global Engineering Education community to tackle these problems by organizing all sort of events like the Global Student Forum (GSF), the World Engineering Education Forum (WEEF), the Global Engineering Deans Council (GEDC) Conference and some other capacity building activities that have gathered thousands of colleagues from all over the world and allowed them to learn from successful experiences and outstanding examples about how to improve Engineering Education.

This book is only one very good example of the kind of outcomes that this 10 years, and still ongoing, effort has produced. Particularly this section includes several papers developed by authors from the Americas, Europe, Asia and Africa about subjects such as research, multinational collaboration, sustainability, industry-academia interaction, ethics, leadership, etc.

A final message to the readers, please let the authors know your opinions and suggestions about the works that you are going to read and connect with them to generate new links for collaboration and mutual benefit.

[1] E.F. Crawley et al., Rethinking Engineering Education, DOI: 10.1007/978-3-319-05561-9_10, Springer International Publishing Switzerland, 2014. Page 231

The Empirical Research on Human Knowledge Processing in Natural Language Within Engineering Education

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Abstract. The state-of-the art of the computer supported or enhanced teaching and learning processes is mostly focused on content acquisition, processing, and management; virtual learning environments; learning analytics; educational data mining. There is an absence of approaches based on knowledge exchange between machines and humans in knowledge based processes. This paper describes such an approach. Within an empirical participatory action research on technology enhanced learning the issue of knowledge is understood as a key element of any automation of human knowledge processing. Teaching is thus considered as a typical knowledge based process. In this context, the utility model is also used, which implemented "virtual knowledge" as a universal construct, which "inter-disciplinarilly" bridges the mental processes of humans and the physical processes performed by computers. Examples of such solutions are briefly mentioned. It is also emphasized that a complex computer supported collaborative learning requires, in the real practice, to execute a combined pedagogic (didactic) and informatics research.

Keywords: Human knowledge processing · Technology enhanced learning · Computer supported collaborative learning · Human computer interactions · Engineering education

1 Introduction

Despite the huge progress in ICT there is still the absence of the computer support of teaching and learning. This absence notably affects the personal level of teachers or students as regards the way how to exchange the flow of human knowledge between humans and machine (computer). This is due to the fact that these processes operate with knowledge and from the informatics point of view they are considered as uncertain processes working with unstructured heterogeneous data. To write computer programs as an abstractions of the real world represents therefore a very challenging problem. In the context of the teaching process there is a need to share such data (human knowledge) between the teacher and many students. In addition, the flow of knowledge must be provided in an appropriate pedagogical (didactic) quality, in real or synchronized time (classroom, at home, online) and within the limited time of the teaching lesson. So logically, these processes should be automated. However, in comparison with

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automation of a technical system, which produces a product with required technical parameters, the teaching is a process within a living system and nobody can guarantee that students are optimally educated, or even that they will understand the pedagogical/content knowledge or be able to use the learnt knowledge in real practice.

In this context, the Cybernetics (within which computers were invented) represents the basic theoretic discipline focused on the automation (regulation, control) of such complex systems, i.e. on the information, information transfer and processing [1]. However, one should always be aware that any computer (machine) can perform physical processes that only support our mental processes, thus, the computer does not perform the mental work instead of us.

On the other hand, we are able to isomorphically assign the results of these physical processes to our intellectual processes [2]. It is also emphasized in [2], that a large part of cybernetics terms is created by the formal and schematic transfer from neurophysiology and social sciences to physical processes. As a result, the concept of analogy is often misused and the terms like information, knowledge, thinking, intelligence have different meanings in Cybernetics, Computer Science, Information and Communication Technology than in Knowledge Management, Education, Educational Psychology, Philosophy, or social sciences respectively.

In general, teaching and learning processes are cognitive processes, i.e. they are human knowledge based, thus logically connected with thinking and intelligence. Within psychology, according to [3], behaviorists understand thinking as a process of solving problems, while in cybernetics it is a process of processing and using information. Similarly, the problem of definition of intelligence is a very complex issue. For instance, in [4], tens of definitions of intelligence are divided into "collective definitions, psychological definitions, and AI research definitions" (AI means Artificial Intelligence). It can be also emphasized that humans acquire human knowledge or information (this is a lower hierarchical level than knowledge) through experience or education, while computers as machines by processing gigantic amount of sequences of bits (as units of information). Therefore, definitions of information or intelligence in various disciplines cannot be the same.

The above mentioned problems also resulted in a relatively large terminological chaos in all interdisciplinary scientific papers focusing on the integration computers into teaching and learning, e.g. concerning Technology-enhanced Learning, Educational Technology, e-Learning, Collaborative Learning, Web-based Learning, including Learning Analytics and Educational Data Mining. These problems were published in many scientific papers, e.g. in [5–11], including authors of this paper during their long-term research on Technology-enhanced learning (see e.g. [12–17]). According to their opinion, the above mentioned terminological issues or the general dissatisfaction with integration of ICT in teaching and learning are related to the absence of scientific approaches concerning the role of knowledge, or definition of knowledge, despite the fact that the human knowledge, including educational knowledge, represents the key element of any automation of teaching processes.

To be terminologically clear, in the title of this paper the term "human knowledge processing" is used in order to differentiate the content of this paper from the concept of information and knowledge commonly used in Computer Science, Artificial

Intelligence, Knowledge Based Systems, or in Educational Data Mining, Learning Analytics, where the meaning of information and knowledge is different.

2 Objectives, Methods and Results

2.1 Objectives

Our research is aimed at the complex all-in-one solution of the automation of teaching and learning with focus on all kinds of processes performed by the teacher as the key player in order to assure his/her sustainability as a knowledge worker who manages the human knowledge based processes. Figure 1 illustrates the basic idea of the teacher's personalized computer support.

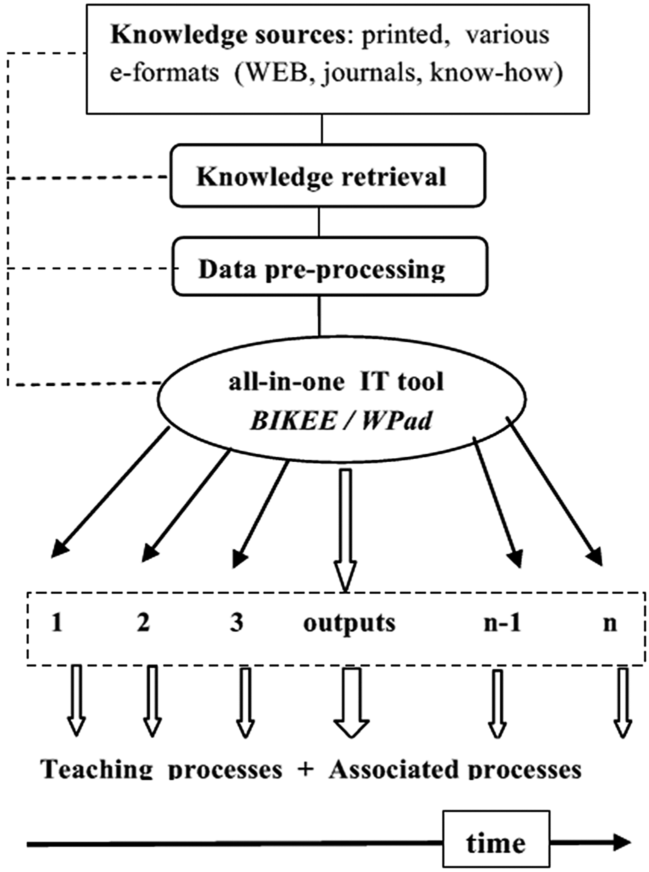

Fig. 1. Schema of the teacher's personalized computer support

This schema illustrates how the knowledge from global or external sources (that is suitable for teaching and learning) is retrieved and processed up to the teacher's needs.

By using our own educational “all-in-one” software BIKEE (Batch Information Knowledge Editor and Environment, written by Svetsky) the teacher generates time outputs for his daily teaching and associated activities (in classroom, online, during his self-study or production of study materials). One specific part of this in-house software, named WPad, which is installed on the classroom’s computers, is used by students for personal or collaborative learning tasks (e.g. they create shared study materials). The empirical research is aimed at automation of all types of activities by integrating computers into teaching and looking for innovative approaches.

Such automation should also extend the teacher’s cognitive skills and mental activities in order to work as a “mental prosthesis”. This covers all categories of teaching. Actually, the focus is on the computer supported collaborative learning that requires pedagogical and informatics research in parallel, including development or innovation of informatics tools and specific software (the all-in-one application using a natural language which is machine readable as well). A specific goal is programming the communication, feedback and mass knowledge production, processing, transfer and utilization within the teacher’s daily teaching. Figure 2 illustrates an example from the research activities of the teacher.

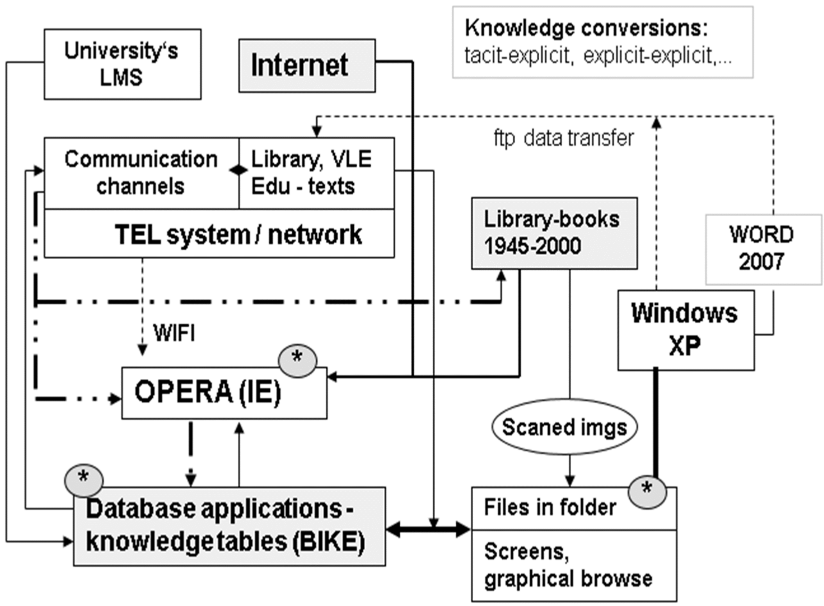

Fig. 2. Schema of modelling Learning Analytics (Source: FP7 Proposal KEPLER)

This schema is from the FP7 ICT project proposal KEPLER (2007). In this case, the objective intended to be attained is the modelling of Learning Analytics in the classroom conditions. However, in comparison with the state-of-the-art in the field of Learning Analytics this approach is focused directly on “human knowledge”, i.e. educational knowledge flow during real teaching, not only on monitoring of activities of students in online learning environments.

Namely, most of the scientific papers describing research on learning analytics are focused on the monitoring and sampling of simple online data during online teaching, e.g. how many logs (visits) the students have performed on the WEB-pages in the learning environment. However, this data is not associated with human knowledge which is essential for any teaching. In principle, the data only represents the result of the associated informatics activity.

This is illustrated by Fig. 3 showing the output of online monitoring by an external service. At the bottom of the figure, the teacher can see the number of students which visited his teaching materials, and at the top of the figure, how many pages were read by them. Thus, he can evaluate students' activities associated with the learning pages. However, one should be aware that it is not associated with their knowledge.

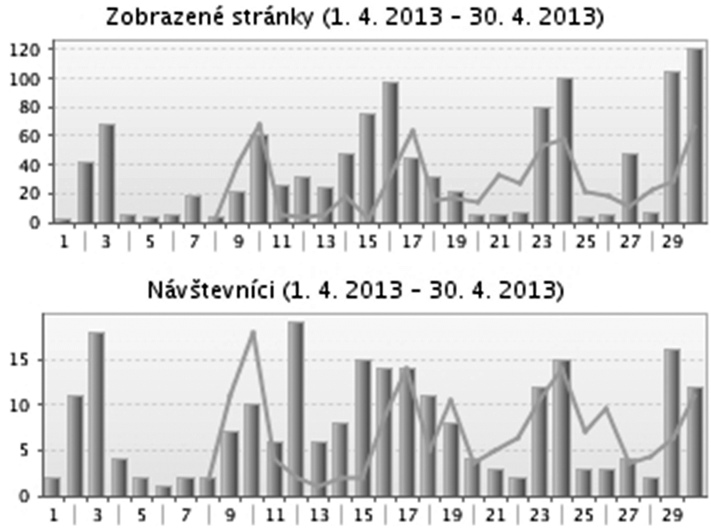

Fig. 3. Example of the monitoring of the visited learning WEB pages by an external service

Because students also used the WPad software in the classroom with computers, it was possible to monitor how many times they visited the online learning pages during teaching (especially when completing exercises). Thus, this enabled the teacher to evaluate the students' classroom activities. For example, there is a virtual calculation tool, at their disposal, for training chemical calculations. So, when the teacher saw, e.g. that student X visited the virtual calculation area five times and student Y twenty times he can suppose that student Y was more motivated for the learning process. On the contrary, he could also consider the possibility that student X had better calculation skills. But the teacher cannot associate these activities directly with their knowledge.

In our case, the teacher also monitored various WEB pages related to certain courses of study. This is illustrated by Fig. 4, which represents a list of WEB pages as they are associated with each of the courses of study.

	stránka	počet zobrazı	%
1	Adresa vyžiadanej stránky nebola zistená	380	18,49
2	http://www.svti.sk/MTF/DP/SKRIPTA/MTFSKRP.HTM	266	12,94
3	http://www.svti.sk/SVTIP.HTM	251	12,21
4	http://www.svti.sk/SVTIL.HTM	228	11,09
5	http://www.svti.sk/MTF/DP/BOZP/BOZPP.HTM	222	10,80
6	http://www.uiam.mtf.stuba.sk/projekt-apw/SV/MI/VCHEMIP.HTM	153	7,45
7	http://www.svti.sk/MTF/DP/SKRIPTA/ZE2009P.HTM	88	4,28
8	http://www.uiam.mtf.stuba.sk/projekt-apw/UBEI/ZESEMPP.HTM	72	3,50
9	http://www.svti.sk/SVTI05P.HTM	53	2,58
10	http://www.svti.sk/MTF/DP/SKRIPTA/SEMPPPP.HTM	45	2,19
11	http://www.uiam.mtf.stuba.sk/projekt-apw/UBEI/IMGS/SEMPRAC/	39	1,90

Fig. 4. Example from the list of the visited learning WEB pages

As it was mentioned, the BIKEE or its part, the educational software WPad, works as the all-in-one, i.e. a multipurpose tool, e.g. as well as a convertor of tacit knowledge into explicit knowledge (according to the terminology of the area of knowledge management). In other words, once a student writes his notes (thoughts/tacit knowledge) into the notepad they represent then the so called explicit knowledge. Therefore, by the monitoring how many times he opened the WPad, such data is more closely linked with knowledge. And this is beyond the state-of-the-art in the learning analytics. This can be demonstrated with the case of the teacher - designer of the BIKEE, who monitored his own activities when starting research on learning analytics. He wrote a specific programming code which indicated how many time the so called knowledge table was opened by him. In this case, such monitoring indicates better how the data is assigned to his activities related to processing the teaching content. Figure 5 represents data from his home computer. One can see that the knowledge table was opened by the teacher around five thousand times within ten months.

```
:: 10 :::: 17.12.2015 || 21:09:40 ::
:: 11 :::: 17.12.2015 || 21:09:55 ::
:: 12 :::: 17.12.2015 || 21:11:35 ::
:: 13 :::: 17.12.2015 || 21:11:35 ::
:: 14 :::: 17.12.2015 || 21:22:01 ::
:: 15 :::: 17.12.2015 || 21:22:02 ::
:: 16 :::: 17.12.2015 || 21:24:39 ::
:: 17 :::: 17.12.2015 || 21:24:40 ::
:: 18 :::: 17.12.2015 || 21:25:52 ::
:: 19 :::: 17.12.2015 || 21:25:52 ::
:: 20 :::: 18.12.2015 || 00:12:47 ::

:: 5250 :::: 03.10.2016 || 20:21:06 ::
:: 5251 :::: 04.10.2016 || 11:39:43 ::
:: 5252 :::: 04.10.2016 || 11:41:40 ::
:: 5253 :::: 04.10.2016 || 12:15:42 ::
:: 5254 :::: 04.10.2016 || 12:15:43 ::
:: 5255 :::: 04.10.2016 || 15:30:20 ::
:: 5256 :::: 04.10.2016 || 15:31:06 ::
:: 5257 :::: 04.10.2016 || 15:31:08 ::
:: 5258 :::: 04.10.2016 || 15:32:18 ::
:: 5259 :::: 04.10.2016 || 15:32:20 ::
:: 5260 :::: 05.10.2016 || 12:29:59 ::
```

Fig. 5. Example from the evidence of opening the personal WPad table by the teacher

Such monitoring could be modified and more deeply tuned by linking data to the content and appropriated metadata of each record in the knowledge tables. However, the following research on learning analytics associated to human knowledge was stopped because the project proposal L3Pulse was not accepted within the FP7 ICT call (2013). Despite this fact, some data is monitored (as can be seen in the Fig. 5) in order to use it within a starting research on developing an educational robot.

2.2 Methods

Our research, which is performed under the umbrella of Technology enhanced learning, represents a typical empiric participatory action research. Within the long-term research a system solution (infrastructure) was built, i.e. personal virtual learning environment, virtual learning space with tutorials, calculation tools, communication channels for each study program (background of environmental protection, chemistry, programming languages, integrated safety), writing of the all-in-one beta software BIKEE and WPad for mass human knowledge processing (the application is installed on each of the class-room's computers or students notebooks). Currently, a teacher's cloud application is being tested, especially the transfer of knowledge between computers, cloud, faculty's server and network. This infrastructure is used for designing innovations and automation of activities in teaching processes. Figure 6 represents such approach within our research on modelling the multilingual support by designing personal corpuses for processing scientific and technological (human) knowledge.

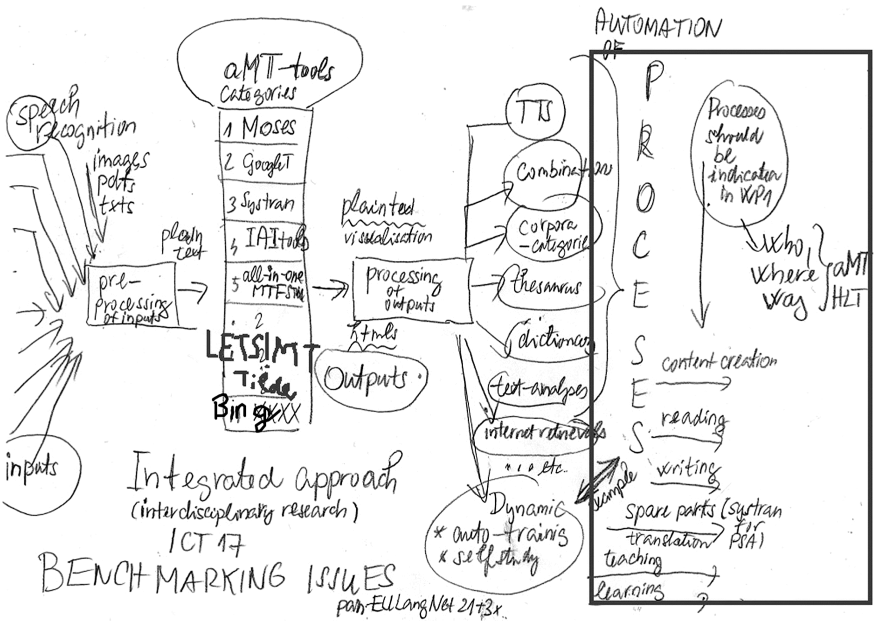

Fig. 6. Schema of benchmarking issues when designing a personal corpus (Source: Horizon ICT 17 Proposal PanEULangNet, 2014)

The idea to create personal corpuses which would contain multilingual human expert knowledge from the machinery engineering area was one of the basic objectives of the CSA project proposal PanEULangNet within the H2020-ICT-2014-1 call (topic

ICT-17-2014). The Proposal title was: "Pan-European Language Network 21 + 3 for designing the infrastructure of Human Processes-driven System of Machine Translation for specialised high-quality Translation". The CSA proposal objectives were focused on cooperative benchmarking for the design of the pilot human processes-driven system of automated Machine Translation (aMT) consisting of research infrastructure of recommended multilingual repositories, specialized corpora, ontological batch knowledge sets, aMT software and a federated trans-lingual pan-European portal. The target was to bridge several EU languages together through technical German language. As it is illustrated by the schema, the BIKEE system could have been potentially developed in subsequent research as the aMT - tool (see No. 5 of the aMT tools categories, i.e. the all-in-one MTF STU on the handmade schema). Due to its multipurpose function, it enables one to pre-process inputs in the plain text format and to produce outputs in the form of various applications needed for the automation of the knowledge based processes which are presented on the right side of the schema (content creation, writing, teaching, learning,…).

It must be emphasised that these processes are very important also from the engineering pedagogy and didactics point of view. Moreover, any processing of the expert knowledge by computers requires a very high level of human-computer interaction (HCI) and represents an extremely difficult task. Namely, despite the enormous progress in ICT, the level of human-computer interaction is still not up to the required level from the IT support of mental processes point of view, because these are uncertain processes using unstructured knowledge and unstructured multi-lingual knowledge respectively. This is the basic barrier to computerisation of human processes. Even though the actual level of IT has overtaken human's abilities by many years, the existing solutions for the so called WEB 2.0 technologies, or Big Data are not suitable for processing huge amounts of scientific and technical information and knowledge. The reason is that such technologies are mostly based on internet applications that utilise very well structured and machine readable data. This fact does not enable knowledge workers to process data in natural language. Moreover, computers are able to process unstructured data only in well-organized processes, i.e. when algorithms within the knowledge based processes would be well known and defined. But this is not our case.

In addition, despite the massive advertising of global players or providers of multilingual machine translation and many existing commercial offers and WEB services these are not yet suitable for translation of technical texts. In this connection, a "hypothesis" was presented in the project proposal that no automatic aMT is able to perform high-quality translations without implementing the human factor. In other words, the actual level of statistics based aMT is not suitable for the engineering practice. For example, at the meeting of the Slovak Technical Committee for Corrosion Protection in April 2014, the quality of translations of CEN and ISO technical standards was evaluated with respect to translations made by translation agencies and aMT. As for the human translators, the problem is the lack of skilled experts, as for the quality of machine translation, this is absolutely unsatisfactory. It has such an impact on the engineering practice that time consuming post-editing is always required. The committee concluded that the key issue is to incorporate terminology and linguistic terminology into Computer Linguistics models and aMT tools.

Similar barriers were indicated by one of the PanEULangNet Consortium's partner from Italy providing translation services. This partner considers the translations of legal texts done by machine translators to be of low quality. The terminology in technical and legal translations is often inaccurate because it does not take into account the specificity of legal systems. Translation errors can be critical as they may have legal repercussions. General translations from and into English are acceptable, while in other languages the quality is low. There are no databases that bring together in one place the legal glossaries that exist in paper form.

According to the partners' experience, the aMT is used in general for the translation of specialized papers, scientific and academic publications, all kind of books, projects and grant proposals, abstracts, newsletters, articles, emails etc. It is used as a starting point in every translation (including agreements, contracts, catalogues, web sites). Very often, field-specific knowledge and expertise is required. It is almost never a "light" superficial editing that is required, very often the machine translated text is unintelligible and the target audience would never be able to understand. Why do people still resort to machine translation if it requires such post-editing process? For two reasons: machine translation provides the first draft with some useful advice on possible translation solutions (it is like a "colleague" of the translator making suggestions you did not think of) and it does speed up the translation process significantly! If you speak a language at intermediate level, aMT is useful when translating into that language. It makes it possible to translate more complex texts than the ones you would be able to do without aMT. But a machine-translated text is far from being directly usable without further interventions as to a great extent it is not even understandable.

When performing a scientific, academic translation, it is necessary to stick to the source text and therefore the translator cannot perform any pre-editing. Moreover, pre-editing takes up too much time to be performed. The main issue however is related to the translation of country-specific concepts: aMT is insensitive to cultural, cross-country differences. In the field of occupational health and safety where regulations vary across countries, as well as the wording used to talk about these issues, aMT makes a mix of legal systems or sticks to US concepts as if they were applicable to every country. It is not culture-sensitive. Also, it is not effective in translating sayings, collocations and field-specific terms, such as: play around: giocato in giro (too literal, meaningless translation in Italian) raise money: alzare, sollevare denaro (translated like "lift money"). With aMT it is almost impossible to vary the register (from formal or informal language) when translating correspondence (email etc.) and also in this case formal language varies from country to country (e.g. British English, US English etc.). These differences are not considered whereas it would be extremely useful. From now on, when doing translations we can collect patterns of aMT mistranslations, if useful.

From the above mentioned one can see that integrating the human factor into aMT systems is very important when solving any automation of processes which uses expert multi-lingual knowledge in general. To be successful in "designing the infrastructure of human processes- driven system of machine translation for specialised high-quality translation" (as it is stated in the title of the project proposal), the researchers need to solve the cooperative benchmarking for the design of the pilot human processes-driven system of automated machine translation. For this purpose, the following five specific workpackages (step by step from WP1 to WP5) were planned as it is illustrated in Fig. 7.

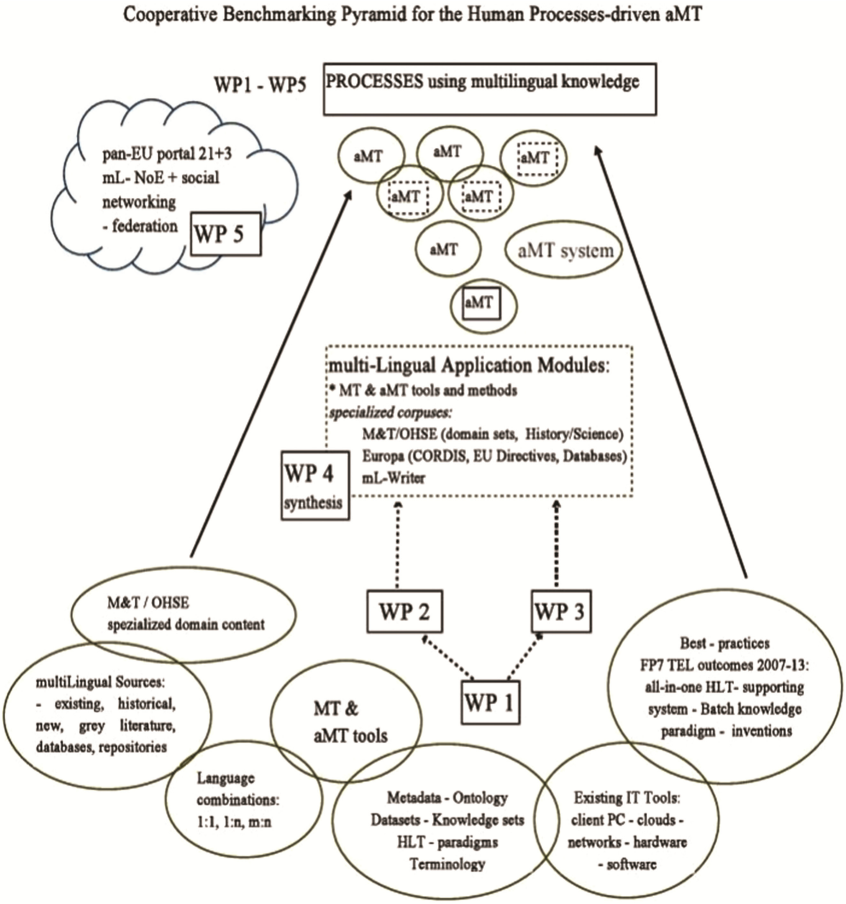

Fig. 7. The cooperative benchmarking pyramid for the human processes – driven aMT

WP1 was dedicated to the state-of-the-art, focusing on selected key expert areas: materials, engineering technology, occupational health/safety, environmental protection. The selected issues were to be benchmarked in WP2 (metadata, ontologies, recommended sources). WP3 dealt with specialised corpora, aMT-systems, translation quality, while WP4 represented the synthesis (applications modules, utility model as a tool for collaborative knowledge building). Finally, WP5 was dedicated to the creation of a pan-European portal for networking activities related to aMT.

In addition, engineering education requires the teacher to solve also many visualizations from the didactics point of view because teaching by using schemas and chemical formulas is needed. However, using the actual global visualization software products for this purpose is often too much time consuming. For example, a more efficient solution than using the common software is to make hand written schemas or formulas on paper or blackboard and using a scanner or digital camera. So we started also with the research on STEM where the visualization is a very important factor [18]. We are actually developing an innovative screenshotting methodology where students' collaboration is used for creating shared educational materials. This represents the case when the pedagogical method, i.e. the creation of the visualized pedagogical content, must be performed primarily. Only after that the integration of IT is possible. In other words, modelling the computer supported collaborative learning requires the combined pedagogic (didactic) and informatics research (it is not possible to write programing codes if no teaching steps exist).

A specific problem in the empirical research on human knowledge processing, as we found out, is the data transfer within the existing informatics infrastructure (computers, cloud, networks, WI-FI devices etc.). For this purpose, the utility model is used, which is related to a system of processing of unstructured data via using a specific data structure - this is just the "switcher" between humans and computers which enables one to perform the mass knowledge processing (it is a part of the registered utility model UPV 7340 by the national patent office 12/2015). This infrastructure is now used for combined pedagogical and informatics research for computer supported collaborative learning (CSCL) in order to model knowledge exchange and sharing.

As was mentioned in the introduction, the key aspect of our methodology is understanding "human knowledge" as the basic element of automation of teaching processes. The utility model employs a specific data structure which works as a virtual knowledge which can be transmitted between online and offline environment (the virtual learning space and environment, cloud, personalized teacher-students network, notebooks, computers in the classroom). In principle, the teacher or students write or input their human knowledge by using natural language into the virtual knowledge (the specific data structure) that is machine readable. In other words, thanks to such possibility the computer can perform a physical process, so the user instantly obtains the suitable results that support his mental processes within teaching or performing associated activities.

2.3 The Results

Based on the results of our long-term research we identified the following three categories: (1) pedagogical - unification of content and teaching processes to be computerized, e.g. research on CSCL methods when modelling the writing of the semester work, incl. producing the shared additional teaching materials directly by the students, (2) informatics - adaptation, personalization, development of IT applications, knowledge transfer via network and cloud, synchronization of blended learning, knowledge base building, the utility model, (3) integrated outputs for daily teaching - CSCL cases of study (automating the writing of semester works, model of teaching the programming languages, additional training materials on chemistry created by students for students), diploma works which were tested for production of eLearning materials by pre-service teachers, or small information systems for technological purposes.

From the research point of view, authors of this paper implemented the term of the "virtual knowledge" as a universal construct, which "interdisciplinarilly" bridges the mental processes of humans and the physical processes performed by computers. In the educational practice, it enables teachers, students, or knowledge workers to process human knowledge in their natural language and on the user friendly basis (the computer makes what they want and need). So, the integration of ICT in teaching and learning can be developed and researched in a natural and effective way.

3 Conclusions

The presented empirical research on Technology enhanced learning is based on the collaboration of humans and computers via a specific data structure, which works as the virtual knowledge unit. Teacher and students input their knowledge into this unit which is controlled by an all-in-one software (BIKEE/WPad). The transfer of knowledge between hardware and software systems (cloud, classroom computers, students' notebooks, WI-FI, networks) is performed according to the above mentioned utility model. This is an optimal background for modelling the knowledge exchange and sharing when solving the Computer Supported Collaborative Learning (CSCL).

Thus, the human knowledge processing in natural language within engineering education is based on modelling the automation of teaching and learning processes, in which the human knowledge is the basic parameter, and by using the batch knowledge processing paradigm performed by specific educational software (BIKEE/WPad), and by transferring the educational knowledge between online and offline environment by using the specific utility model. This enables the teacher to perform various teaching activities and solve pedagogical innovation research tasks, including associated processes (writing papers, solving multi-language support, producing teaching and study materials, advanced searching and retrieving, performing combined online/off-line self-study activities etc.).

According to our latest findings, it seems that the number of actions related to one learning content item requires the researcher to perform a lot of informatics actions related to file management, instructions and cognitive activities (communication, feedback). Therefore, this is a new challenge for designing the educational robot or an educational intelligent system.

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Study on Interest and Perception of Value in Multinational Collaborative Design Projects Among Engineering Students

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Abstract. The level of interest and perceived value of engineering students in a multinational collaborative design project experience is reported in this paper. The report establishes a comparison based on geographical location and class standing of the participants. For this purpose, a survey was used to collect demographic data and students' feedback on questions based on the Intrinsic Motivation Inventory (IMI) survey, which permits to evaluate five constructs, being interest and perceived value the ones considered in this work as indicators of motivation. The data was collected from students participating in the collaborative design project. These students were at seven institutions in six countries (USA, Honduras, Ecuador, Brazil, Chile, and Italy). The analysis of the data collected shows that students have a high level of interest and value the experience, with some numerical differences based on geographic location and class standing, but only significant difference based on class standing. These results are of importance when considering multinational collaborations in a generation of students moving towards a smart society, indicating a level of motivation that is mainly affected by academic maturity.

Keywords: Multinational projects · Interest · Value · International collaboration

1 Introduction

For many years instructors have discussed the advantages and disadvantages of inductive and deductive teaching and about which of these two methods is better for students' learning. The literature on this topic is ample as well as the research work and the experimental studies about it [1, 2]. The progress in education has led to teaching methods increasingly tailored to satisfy the needs of specific topics of study, and new

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questions about effective educational approaches are flourishing daily, particularly when smart society is considered, demonstrating that education research is an alive field in constant development and evolution [3, 4].

The development of new educational methods has been favored by the existing awareness that, in order to obtain a deeper understanding - conceptual and functional - of the material proposed to the students, the material itself has to be presented in an adequate form and students have to be engaged and motivated on activities able to integrate theory and practice. The aim of all such activities is to reduce the boredom of the students and move the knowledge they have acquired from a superficial level to one of a greater awareness, inducing new motivations in the students. For this to happen, students have to be actively engaged into constructing their own experiences, similar to what happens during laboratory testing in scientific disciplines. It is proven that when the learning is situated in a real context, the capacity to acquire the meaning of the phenomena observed is greater [5].

One of the most widespread learning methods is Project Based Learning (PBL) that proposes the involvement of students in activities very similar to those they will face in their professional life, offering them the opportunity to be engaged in the development of a feasible solution to a real problem. The PBL method allows students "to learn by doing and applying ideas" [6]. In this learning methodology, students are called to find solutions to driving questions while collaborating in teams under instructors' supervision. Such pedagogical approach has been incorporated in courses at all educational level and it has become widely accepted and applied in the academic setting. This is due not only to the fact that the methodology facilitates the learning experience of a subject by getting immerse in the solution of the problem, but also because of the ability that the method has to increase students' professional skills. These competencies, known as Dublin's descriptors and considered fundamentals for forming the European students [7], include knowledge and understanding (fundamentals and application), the capacity of learning and communication skills, and the ability of making an autonomous judgement, all of which can be gained through PBL.

Today's society is demanding that the people that will be in the working force of tomorrow's world be prepared and ready to be productive in the expected smart society. In a global business environment, there is the expectation that all members of a professional workforce have a set of global competencies that will make them more productive. Globalization is constantly changing various aspects in society, particularly the process of knowledge creation and dissemination [8]. The formation of multinational partnerships is a common practice in the corporate world nowadays, with the aim of taking advantage of a diverse and rich knowledge platform dispersed throughout the world. Geographically spread teams are now working together not only to create new products but also to discover solutions to great global challenges. These multinational teams are being supported by rapidly growing information technology capabilities, which facilitate their creation and functionality, one of the foundations for a smart society. Hence, modern competitiveness around the world requires preparing professionals who are able to face all sorts of technical endeavors by sharing their competencies in global environments and through the use of virtual tools. As a result, there is a growing demand to prepare professionals to be ready to perform in multinational environments. The engineering education should not be solely focused on preparing students to solve local or national issues, but also in educating world-class engineers capable of working as well on global challenges. Similarly, globalization has resulted in many companies having operations in several countries, so engineering students should also be prepared to work in global projects with multicultural teams.

In response to the demands for global professional skills, a PBL educational activity engaging students in multinational teams located in different countries has been adopted by several institutions in order to improve students' collaborative and communication skills in an international and diverse setting. Such a study is the core of the project presented here. However, the effectiveness of this practice had not been rigorously evaluated until recently when formal studies of different aspects of this practice were initiated. The aim of these studies was the improvement of the students' learning experience to attain the desired goals. Initially, the interaction among the participants was studied by the authors and identified as an important issue for the success of the practice [9]. That work let to new questions to understand better the behavior of the students during their involvement and interaction in the collaborative project. One of these questions was related to the motivation that students had about this practice. Based on a literature review, it can be stated that motivation is an important factor that includes interest, which is an important construct that contributes to the learning experience [10]. In the particular case of engineering, some efforts have been done to evaluate and enhance motivation in the students [11] with the aim not only of succeeding in specific topics but also to enhance students' self-efficacy and self-confidence in the field [12–14].

This paper presents the results of an evaluation to determine the level of interest and perception of value of students participating in an engineering multinational collaborative design project. These constructs were used to evaluate the students' motivation when given the opportunity to participate in such multinational project. The comparison presented is based on geographical location and class standing, which are demographic characteristics that the authors believe have a direct influence in the students' motivation. The evaluation was done with a survey administered to more than 200 students at seven institutions in six different countries, and students from five levels of academic experience.

2 Background

2.1 Motivation, Interest, and Self-efficacy

Motivation involves internal processes that activate behavior's persistence, energy, direction and excitement, and originates from a variety of sources, such as needs, cognitions and emotions, and these internal processes energize the behavior in multiple ways [15, 16]. Jones [17] defines academic motivation as physical activities and a mental disposition directed toward specific objectives that can be sustained in time, concluding that it is important in education because it engages students in the learning activities and helps them to reach high academic goals. It has been reported that motivated students tend to pay more attention to coursework, take time to use effective learning strategies, and look for help from others when necessary [18]. Weber [19] established a strong correlation between interest and intrinsic motivation in students determining that intrinsic motivation is an important driver in students learning while the external motivation is not. This agrees with the assertion from Hidi and Renninger [20] who state that interest includes situational interest (immediate, short-term enjoyment of instructional activities) and individual interest (internally activated personal values about a topic) that tends to be more lasting. In their case, the individual interest is related to intrinsic motivation while situational interest is closer to external motivation.

Alexander et al. [21] established the relationship between interest and learning. In such work, it was concluded that students interested in a subject would learn it better than students not interested would. Therefore, the relation between motivation, interest and academic success is strong [22]. The academic motivation is directly and indirectly influenced by the learning processes [23]. The usefulness component of an educational model relates to the degree to which students believe course activities have value for their goals [24]. Therefore, it is important that all learning activities are prepared to stimulate the motivation for the subject in students because it is necessary to trigger the interest in all learning activities [25]. Another key element in students' continuous progress and retention is steady development of self-efficacy. According to Bandura [26] self-efficacy can be defined as one's perception of capability in organizing and executing actions that accomplish desired tasks. It was determined that the course of action that people chooses to follow is influenced by their self-efficacy. Likewise, the amount of effort put forth into a specific task and the level of perseverance are also affected. Thus, educators in general are emphasizing the importance of understanding the methodologies employed to enhance self-efficacy [27].

2.2 Project-Based Learning

In recent years, teaching and learning methods at the university level have experienced a transformation aimed to increasing active learning in the classroom [28]. The concept behind this learning method is to connect students directly and engage them actively in the learning process. The Project Based Learning (PBL) method, is one of the most effective ways to engage students with learning content and is strongly recommended by several educators as one of today's best education practices [29]. In the PBL, the learning process is centered on the student who works in a group project to solve a real situation proposed by the instructor. Another characteristic of the PBL is that in the projects, students engage in a constructive investigation that involves inquiry, knowledge building and resolution. Therefore, PBL challenges students with real problems, promotes collaboration among students in conducting their investigations, and encourages students to incorporate and fuse their knowledge in order to solve the presented problems. While working on these projects, students develop cognitive tools that facilitate future learning [30–32].

Several advantages in student learning were related to PBL as motivation to work hard, responsibility, maturity, proactivity, better preparation for professional life, learn to learn, learn to work to agreed deadlines, communication skills, higher level thinking skills, new learning resources, variety of learning styles [33, 34].

Realistic and authentic engineering experience gained through PBL aims to expedite a sense of domain mastery leading to increase in self-efficacy in engineering field. Close relation between self-efficacy and motivation has been observed, as students' motivation grows with their confidence in their ability to accomplish successfully assigned tasks [35]. The tasks should be challenging but not perceived to be beyond capability. One might comprehend the task to be beyond his/her capacity and deviate from the task in favor of activities perceived as more rewarding, or easier to accomplish. However, establishing sub-goals for a complex distant goal might be perceived to be within one's level of self-efficacy. Sub-goals set correctly, when accomplished, can increase self-efficacy by mastering sub-activities. This will lead to greater students' commitment to complex distant goals.

According to Ponton et al. [36], there is a close interrelation between self-efficacy, cognitive motivation and valuable outcomes. This relation determines the type of actions followed by each individual to reach the desired outcomes. This is very important when an educational experience is introduced in the classroom and it is expected students take full advantage of it. However, characteristics of people such as feelings, opinions or attitudes are known as latent constructs, which are unobservable traits that cannot be observed directly, and need to be measured through indicators that can be captured in a scale format [37]. Therefore, the students' interest and perception of value for multinational collaborative design projects have to be measured through an instrument based on scaled indicators.

2.3 Collaborative Projects

A group of institutions in the Americas and Italy has used for several years multinational collaborative design projects as part of their engineering education experience with the aim to foster global competencies in engineering students. These projects are in-class and same-term assignments that usually last eight weeks and bring together groups of students from different countries to work as a team in a design challenge. Teams of students are formed at each participating institution and clusters of teams are formed internationally to promote interaction as well as exchange of information and ideas while working on a solution for the problem assigned. All teams receive the same design project in the different institutions. Students are asked to work with the other teams in their cluster by using formal tools for communication (i.e., email, web-based meeting rooms for audio-video conferences, and platform to exchange files), but are also allowed to use informal tools for social interaction (e.g., social networks) to build trust and enhance the overall interaction among the international teams.

The challenges faced by students in these collaborations are not trivial ones because those include aspects such as differences in language, culture, and educational background, as well as the requirement to work across different time zones [38], with all of them representing typical competences required by today's companies from their professional workforce [39]. Besides, students are also required to develop their capacities to use information and communication technology tools to share information with their international partners.

This type of experiences became a test rig to understand the most suitable mechanisms to allow a better involvement of students and to improve the effectiveness of such pedagogical methodology. One of the most critical questions about this educational activity is the one related to the students' motivation and interest in participating since these aspects are critical to the success of this academic experience. In fact, the relevance of the information shared among the cluster of teams and their interaction are conditioned by the desire of any single student to participate in the activity. Additionally, motivated students will have the disposition to overcome the project difficulties, and recognize the value of the experience for their professional future.

The work presented here is a novel effort to assess the level of motivation self-reported by students when they are assigned the multinational collaborative design project. Even though there are different instruments that capture different factors to determine the level of motivation showed by an individual [40], the Intrinsic Motivation Inventory (IMI) [41] provides the set of questions to capture interest, perceived competence, pressure, perceived choice, and value. Two of these constructs are used in this study to evaluate motivation level in a multinational collaborative design project.

3 Objectives and Research Questions

Results from previous work [13] led the authors to believe that motivated students will:

(a) have the interest necessary to get immerse in a project;
(b) have the disposition to overcome difficulties in the development of a project - including broken communication, level of commitment, and cultural barriers;
(c) recognize the value of the PBL multinational experience.

If those elements are present, then it is expected that students will enhance their confidence when undertaking collaborative multinational design projects, perform better in the tasks, including effective teamwork and communication, and appreciate the global experience. Therefore, the aim of this work is to evaluate the interest and perception of usefulness of assigned collaborative multinational design projects in engineering students at different locations in the USA, Latin America and Italy, and with various class standings. The purpose is to have an understanding of those critical factors to answer the following research questions:

1. Do students enter into the multinational collaborative project with a high level of interest and a high perception of value for this activity?
2. Are there significant differences on interest and perception of value among the students based on their geographical location, or class standing?

4 Methodology

Since the purpose of this study is to evaluate interest and perception of value of an academic activity, both of which are latent constructs that cannot be measured directly or objectively, a survey based on the Intrinsic Motivation Inventory (IMI) [13] was used to capture students' perception before their participation in the multinational collaborative design project. This is a deductive and descriptive study that captures qualitative data through a survey to quantify it (i.e., mixed methods). The first four questions in the survey are about demographics that will help to compare the answers based on student location and class standing, among others. Then, 27 statements are given and students are asked to give their personal level of agreement to those statements. These 27 statements were selected from a full IMI survey, and modified to relate specifically to the collaborative design project. Their answers are based on a Likert scale ranging from one to seven, where one is "not at all true" and seven is "very true". Those 27 statements are distributed into the five constructs for motivation defined by Deci and Ryan [42]: interest/enjoyment (7 statements), perceived competence (5 statements), pressure/tension (5 statements), perceived choice (5 statements), and value/usefulness (5 statements). The five motivation constructs are to be measured and calculated as described in Table 1. The average value of each survey items should be added accordingly and in the case of the reverse values (indicated as "R" in the Table), these are to be calculated by subtracting 8 to the measured values.

Table 1. Survey items and motivation buidling constructs.

Construct measured	Survey items used
Interest/Enjoyment	1, 6, 9, 12, 17(R), 21, 24
Pressure/Tension	2(R), 7, 11(R), 16, 22
Value/Usefulness	5, 10, 14, 19, 27
Perceived competence	4, 8, 15, 20, 26
Perceived choice	3, 13(R), 18, 23(R), 25(R)

Since the survey used was constructed from the IMI, which has been thoroughly tested [42], it is not necessary to perform a factor analysis of each construct. However, the reliability and internal consistency of the complete instrument and the individual constructs need to be assessed through a Cronbach's alpha analysis. If Cronbach's alpha values superior to 0.7 are achieved the instrument and constructs can be considered reliable [43], otherwise adjustments must be made in the corresponding low-score factors in order to obtain the reliability and consistency required. Finally, using the results from the survey, the specific construct values can be measured and the corresponding analysis can be performed.

Considering that studies have shown that hands-on classes (i.e., active learning) which are highly aligned with what industry are currently demanding increase the level of motivation of students [44], it is fair to assume that a course centered around a multinational collaborative design project would be highly motivating for students. Similarly, it is also fair to assume that students would consider that a class activity teaching them how to deal in such type of environment would be highly useful for them in their professional formation. This is because globalization is an evident trait in our current market, and students, regardless of their geographical location or class standing, are aware that the most successful corporations are multinational with branches and operations throughout the world.

To test the first research question posed, the following hypotheses are stated:

H_{1a}: Students enter into the multinational collaborative design project with a high level of interest.

H_{1b}: Students enter into the multinational collaborative design project with the belief that the experience will be of value for their career.

Both of these hypotheses will be tested using a t-student unilateral test with respect to the 70% value of the maximum motivation possible, according to the construct measurement.

To test the second research question, the following hypotheses are stated:

H_{2a}: Students enter into the multinational collaborative design project with a similar interest regardless of their geographic location.

H_{2b}: Students enter into the multinational collaborative design project with similar interest regardless of their class standing.

H_{3a}: Students enter into the multinational collaborative design project with similar beliefs regarding the value of the experience for their professional career regardless of their geographical location.

H_{3b}: Students enter into the multinational collaborative project with similar beliefs regarding the value of the experience for their professional career regardless of their class standing.

These hypotheses were tested using analysis of variances test (ANOVA) comparing the responses for location and class standing.

5 Results

From a total of 218 surveys submitted by students participating in the global collaborative project, 182 were completed correctly (83% response rate). The survey was designed online and students completed the questionnaire before they started the project. Students were told that their participation was anonymous, voluntary, that their participation would not affect their academic evaluation, and that all information would be confidential. The survey was administered in English.

Descriptive statistics were performed using standard statistics software. From a preliminary analysis, it can be seen (Fig. 1) that there was a higher percentage of participation from first, second and fourth year engineering students. Also it can be seen (Fig. 2) that the gender of participants is in line with typical breakdown in engineering [45], and the distribution per country is presented in Fig. 3.

A Cronbach's alpha analysis was performed in each of the constructs and the complete instrument and it was found that the "Pressure/Tension" and "Perceive Choice" construct were below the 0.7 threshold value. The analysis showed that removing questions 16, 18 and 23 would improve the reliability of the instrument. This reduction was performed, even when the constructs considered in this study are interest/enjoyment and value/usefulness. As it is shown in Table 2, after the reduction was performed, acceptable alpha values were achieved for each construct and for the complete instrument.

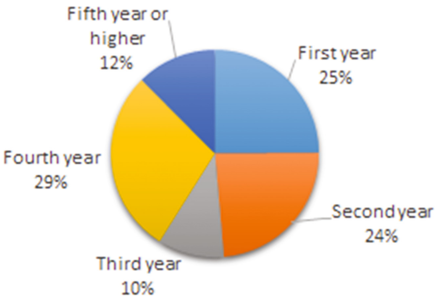

Fig. 1. Class standing distribution

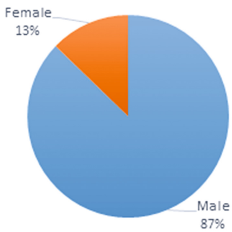

Fig. 2. Gender distribution

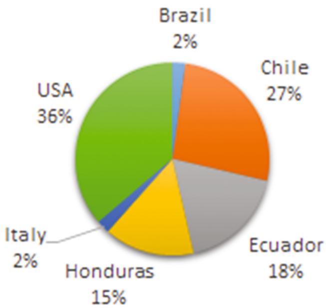

Fig. 3. Geographical location distribution

Table 2. Cronbach's alpha results

Scale	Cronbach's Alpha	No. of items
IMI instrument (all data)	0.856	27
Interest/Enjoyment	0.931	7
Pressure/Tension	0.752	5
Value/Usefulness	0.884	5
Perceived competence	0.828	5
Perceived choice	0.728	5

For the first research question (i.e., level of interest and perception of value), $\boldsymbol{H}_{1a}$ and $\boldsymbol{H}_{1b}$ were tested. To measure if $\boldsymbol{H}_{1a}$ was true, the variable "Interest/Enjoyment" needs to be high, as that subscale is considered the self-report measure of intrinsic motivation in the Intrinsic Motivation Inventory (IMI). This was measured in the following way:

$$\boldsymbol{H}_{1a} : \boldsymbol{\mu}_{Interest} \geq 70\%$$

where:

$$Interest = \frac{Q1 + Q6 + Q9 + Q12 + (8 - Q17) + Q21 + Q24}{49} \times 100\%$$

To measure if $\boldsymbol{H}_{1a}$ was true, the variable "Usefulness/Value" needs to be high. This was measured in the following way:

$$\boldsymbol{H}_{1b} : \boldsymbol{\mu}_{Value} \geq 70\%$$

where:

$$Value = \frac{Q5 + Q10 + Q14 + Q19 + Q27}{35} \times 100\%$$

According to the performed evaluation, both hypotheses were confirmed true as students displayed a high level of intrinsic interest towards their participation in the multinational collaborative design project, and the majority of students expected this experience to be of great value for their education. As it can be seen in Table 3, this is concluded based on the average overall scores collected from the survey (74.5% of the maximum possible score in the interest construct and 83.1% of the maximum possible score in the expected value) and their p-value < 0.05, which rejects the null hypothesis and supports the proposed hypothesis. As additional information, it was also notable the low level of pressure they expected to experience for participating in the program (54%) and the high level of preparedness (competence) they felt they already had to undertake the collaborative design project (73%).

Table 3. Test statistics for Hypothesis 1 (interest and value high)

Variable	Avg. score	Stand. dev.	p-value	Conclusion
Interest ($\boldsymbol{H}_{1a}$)	74.5	18.1	0.000	Do not reject hypothesis
Value ($\boldsymbol{H}_{1b}$)	83.1	14.7	0.000	Do not reject hypothesis

For the second question, i.e., effect of geographical location and class standing on interest and perceived value, $\boldsymbol{H}_{2a}$ and $\boldsymbol{H}_{2b}$ were tested to see if there were significant differences in the interest of the students based on geographical location and class standing by using an ANOVA test. Then, this was measured in the following manner:

$$\boldsymbol{H}_{2\mathbf{a}} = \boldsymbol{\mu}_{Interest(BRA)} = \boldsymbol{\mu}_{Interest(CHI)} = \boldsymbol{\mu}_{Interest(ECU)} = \boldsymbol{\mu}_{Interest(HND)} = \boldsymbol{\mu}_{Interest(USA)} = \boldsymbol{\mu}_{Interest(\mathrm{ITA})}$$

$$\boldsymbol{H}_{2\mathbf{b}} = \boldsymbol{\mu}_{Interest(\mathrm{Y1})} = \boldsymbol{\mu}_{Interest(\mathrm{Y2})} = \boldsymbol{\mu}_{Interest(\mathrm{Y3})} = \boldsymbol{\mu}_{Interest(\mathrm{Y4})} = \boldsymbol{\mu}_{Interest(\mathrm{Y5+})}$$

Similarly, $\boldsymbol{H}_{3\mathbf{a}}$ and $\boldsymbol{H}_{3\mathbf{b}}$ were tested to see if there were significant differences in the value of the activity based on geographical location and class standing by using an ANOVA test. Then, this was measured in the following manner:

$$\boldsymbol{H}_{3\mathbf{a}} = \boldsymbol{\mu}_{Value(BRA)} = \boldsymbol{\mu}_{Value(CHI)} = \boldsymbol{\mu}_{Value(ECU)} = \boldsymbol{\mu}_{Value(HND)} = \boldsymbol{\mu}_{Value(USA)} = \boldsymbol{\mu}_{Value(\mathrm{ITA})}$$

$$\boldsymbol{H}_{3\mathbf{b}} = \boldsymbol{\mu}_{Value(\mathrm{Y1})} = \boldsymbol{\mu}_{Value(\mathrm{Y2})} = \boldsymbol{\mu}_{Value(\mathrm{Y3})} = \boldsymbol{\mu}_{Value(\mathrm{Y4})} = \boldsymbol{\mu}_{Value(\mathrm{Y5+})}$$

Using the results from the administered survey, the results are summarized in Table 4. As it can be observed in the table, in the case of the geographical location, the interest of students towards the multinational collaborative project and their belief regarding its value for their professional career show no significant differences in all countries involved. In the case of class standing, the students' perception of value and their anticipated interest show significant differences between students from different class standings, with a decrease as the students have higher class standing. Of interest is to note that even when not statistically significant, there is a higher perceived pressure based on class standing, particularly between third year students compared to first and fifth year students.

Table 4. Test statistics for Hypothesis 2 and 3

Variable	F	Sig.	Conclusion
Interest filtered by country ($\boldsymbol{H}_{2\mathbf{a}}$)	2.087	0.069	Do not reject hypothesis
Interest filtered by class standing ($\boldsymbol{H}_{2\mathbf{b}}$)	3.143	0.016	Reject hypothesis
Value filtered by country ($\boldsymbol{H}_{3\mathbf{a}}$)	1.278	0.275	Do not reject hypothesis
Value filtered by class standing ($\boldsymbol{H}_{3\mathbf{b}}$)	3.422	0.010	Reject hypothesis

Results indicate a high level of interest and perception of value in the multinational experience, with no significant differences due to specific geographic location but with some differences based on their class standing.

6 Conclusions

The motivation by engineering and engineering technology students to be part of collaborative multinational design projects has been studied. Evaluation of two particular constructs of motivation, interest and perceived value, is done as a function of two demographic parameters of relevance for multinational projects, geographic location and class standing. A questionnaire based on the IMI was used as instrument for evaluation of the participants from seven academic institutions at six countries.

From the results, it can be determined that both interest and perception of value were at high level in the students responses, with some numerical differences based on geographic location and class standing. However, no statistically significant differences were observed on interest and perception of value based on location, but there was a decrease in that interest and perception of value with students with more years of college experience (higher class standing). Additional observations during the project and preliminary results of exit surveys show that the level of interest diminishes during the duration of the project. More research on this observation will follow to determine possible causes and create appropriate intervention actions to maintain a high level of motivation and, as consequence, an academic experience conducive to reach the expected learning outcomes.

The attractiveness of the experience for the students is high but the capacity to maintain a good level of motivation seems influenced by the trend assumed of the project. In particular, personal interactions between the participants assume an important role to the success of the experience. The language and cultural differences can influence the work of the cluster as well as the compulsoriness of the activity for some teams produces a different interest in the participants. Keep into account of these aspects during the preparation of the activity should permit to obtain better results concerning the motivation.

The results from this study are a useful guideline in the definition of PBL activities where multinational collaborations are planned. In current and future professional environments, it will be essential to have such guidelines in order to address the expectation being placed by the coming smart society.

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Managing Industry Sponsored Capstone for Learning & Customer Satisfaction

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Abstract. Capstone ranges across the spectrum as to how it is taught at various universities. Regardless, capstone's purpose is to give the students an experience which includes technical education while emphasizing the aspects of: producing a product, planning, team work, project management, economics, safety for all, ethical behavior, and much more. Mechanical Engineering at the University of Kansas uses a three-course capstone sequence. The first course targets fully preparing students so that they've seen and done a complete project before tackling their main capstone project. For the two following courses, this allows planning their capstone projects and focusing on actually doing their projects. For project management, two faculty members handle the management and technical aspects of the design process; and the Sponsor is the Client, who wants a final product for its customers. This requires students to trade off the conflicting demands of "two bosses" and a Client, and requires that students learn to make priority decisions to accomplish their projects. Challenges are to improve Sponsor engagement, better engage students in the first course, and help students address conflicting direction from multiple bosses.

Keywords: Capstone · Senior design · Course sequencing · Sponsor engagement · Student engagement · Conflicting direction · Design process · Technical design · Project management

Nomenclature

ABET	Accreditation Board for Engineering and Technology (over the years, ABET has expanded to include accreditation of Computer Science and Applied Science programs)
Capstone	Culminating experiential student project; also sometimes referred to as 'Senior Design'
Capst1a-1	Solid mechanics emphasis capstone course. Initially, students were required to take either Capst1a-1 or Capst1a-2. Both courses included "how to design" and a design project which was usually faculty initiated/developed; and both courses were one-semester long, taken in the last semester of the senior year
Capst1a-2	Thermo-fluids emphasis capstone course. Initially, students were required to take either Capst1a-1 or Capst1a-2. Both courses included "how to design" and a design project which was usually faculty initiated/developed. and both courses were one-semester long, taken in the last semester of the senior year

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Capst1b-1	Solid mechanics emphasis capstone course. Students were required to take both Capst1b-1 and Capst1b-2, in order to become familiar with producing designs in both major sub-areas (solid mechanics and thermo-fluids) of ME. Both courses included "how to design" and a design project which was usually faculty initiated/developed. Both courses were one-semester long; and students could choose which course to take in which semester of the senior year
Capst1b-2	Thermo-fluids emphasis capstone course. Students were required to take both Capst1b-1 and Capst1b-2, in order to become familiar with producing designs in both major sub-areas (solid mechanics and thermo-fluids) of ME. Both courses included "how to design" and a design project which was usually faculty initiated/developed. Both courses were one-semester long; and students could choose which course to take in which semester of the senior year
Capst2b-1	Junior level "how to design" one-semester course, taken in the second semester of the junior year. This course did not include an open-ended design project, but did have faculty-developed example projects
Capst2b-2	Senior level open-ended one-semester design project, taken in either the first or second semester of the senior year. This course used either faculty-developed projects or outside-KU-ME projects. Very seldom were these industry sponsored
Capst-A	First semester of a two-semester senior level open-ended design project, which can be started in either the first semester of the senior year or last semester of the junior year. This course uses almost exclusively industry sponsored projects
Capst-B	Second semester of a two-semester senior level open-ended design project, which can be in either the first or second semester of the senior year. This course uses almost exclusively industry sponsored projects
Capst-prep	Junior level "how to design" one-semester course, taken in the second semester of the junior year. This course does not include an open-ended design project, but does have faculty-developed example projects
Cornerstone-A	Freshman level course which includes a significant design problem. This course is heavily CAD oriented; and a student team from this course works with a student team from the Cornerstone-B course on a project that is developed by the faculty member who is simultaneously teaching both Cornerstone-A and Cornerstone-B
Cornerstone-B	Freshman level course which includes a significant design problem. This course is heavily Elementary Programming oriented; and a student team from this course works with a student team from the Cornerstone-A course on a project that is developed by the faculty member who is simultaneously teaching both Cornerstone-A and Cornerstone-B

Fr	Freshman standing (approximately first year) in the KU-ME curriculum
IP	Intellectual Property
Ju	Junior standing (approximately third year) in the KU-ME curriculum
KU-ME	Mechanical Engineering Department at the University of Kansas
NDA	Non-Disclosure Agreement
Se	Senior standing (approximately fourth year) in the KU-ME curriculum
So	Sophomore standing (approximately second year) in the KU-ME curriculum

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1 Introduction

From the published literature, there are a number of organizational structures used to deliver the capstone experience to engineering students. Of course, the goal of each organizational structure is to provide the "best" preparation for undergraduates to meet the various demands of engineering design as applied to governmental, industrial and non-profit settings. Thus, educational institutions strive to make that preparation as broad as is reasonable, while still giving as many specifics of the design process as possible. This paper focuses on three aspects of senior design capstone systems that have been developed across engineering disciplines: optimizing capstone course sequencing, deeply involved capstone project sponsorship, and effective project management with the inherent ambiguity arising from that management.

In order to best prepare students for product design in the engineering workforce, it is clear that it would be best for students to experience the design process from their freshman through senior years (Zhan et al. 2009). This is difficult to achieve, as a tradeoff exists between such experiences and the fact that a series of fundamental engineering concepts must also be taught during those four to five years. In addition, freshmen may not have enough fundamentals to address engineering design projects. Ideally, if students could focus on one project [with several shorter-term projects as needed] during their academic careers and see that project evolve as they added more fundamental skills along the way, this could give them a balanced and integrated learning experience. The rationale for this structure is that the learning experience should be as integrated as possible, and not entirely sequential. An alternative to the "one overall project" approach is to give the students experience with design projects along the way, but, at each step, tailor that experience to fit their current level of skills and knowledge. This was proposed by Zhan et al. (2009). University of Kansas Mechanical Engineering (KU-ME) currently uses a pair of freshman "cornerstone" courses to help provide these types of experiences. Student "design overload" could be an issue, so possibly one course/year would be sufficient to reinforce the concepts needed (Bell-Huff et al. 2016).

Carrying this theory to its extreme conclusion could result in a variety of excellent student experiences that are not linked by underlying engineering fundamentals. Thus, it's obvious that a carefully integrated approach is needed, as exemplified by such efforts as that outlined by Eppes et al. (2012). However, it is also clear that capstone must teach much more than just applying engineering fundamentals to a project. Hackman et al. (2013) indicate that students must be prepared for handling non-technical issues such as: economics, intellectual property, liability, patents, all forms of communication, professional interaction with clients/co-workers/supervisors/regulatory-agencies, leadership, project planning and management, and ethical behavior – including the wide-ranging ramifications of each of these. Possibly more than design "integration across the curriculum" and the need to "provide a strong technical design experience", these non-technical issues have driven the push for intensive capstone course sequences that exceed what a single course can provide. Some institutions have gone to one and one-half semesters (Hackman et al. 2013); two-semesters/3-quarter, or equivalent (Gananapragasam 2008; Eggermont et al. 2010; Nassersharif and Riley 2012; Trent and Todd 2014); three semesters, at KU-ME and Liberty University (Pettiford 2014); and even four semesters (Pierrakos and Barrella 2014). Howe (2010) breaks down the distribution as of 2005 (1 semester capstone = 43%; 2 sem = 37%; 1 quarter capstone = 8%; 2 qtr = 3%; 3 qtr = 5%; other = 4%). Over the ten years preceding 2005, that study showed a small increase in the number of semesters or quarters committed to capstone; and, from the number of publications regarding capstone, that trend appears to have continued, possibly accelerated, during the most recent ten year span. Also, additional support resources (e.g., faculty and volunteer resources as advisors, mentors, etc.) (Hackman et al. 2013) have been applied in order to help greatly improve capstone success – measured as to quality of academic skills and degree of preparation for the engineering workforce.

Due to the perceived quality of the educational experience, most educational institutions have adopted the "external sponsor" arrangement for capstone design (Gananapragasam 2008; Trent and Todd 2014). Intellectual Property (IP) and Non-Disclosure Agreement (NDA) issues have been noted by Hackman et al. (2013). These are important issues which must be addressed to fit each institution's situation. Hackman et al. also noted that their team sizes had increased to six to eight students per team, and indicated that team organization, interaction, and success, as well as individual team member learning/experience, were issues of concern. Selecting projects so at to have a reasonable level of challenge was also Hackman et al.'s concern.

In order to encourage high quality external sponsorship, KU-ME has developed what appears to be a fairly unique arrangement in engineering higher education. This arrangement allows the Sponsor to retain all IP rights. By implementing this arrangement, Sponsors are encouraged to function as full partners, helping to maximize benefit to all involved in the capstone program. This is different than what's been detailed in much of the published literature (Dozier and King 2012).

As stated previously, this paper focuses on capstone course sequencing of the design process in KU-ME, as well as the level of Sponsor involvement. The paper also addresses the multiple people involved in project management and the conflicting guidance that can result. For KU-ME, there are freshman, junior and senior year design experiences, with senior year being the capstone project (see Table 1). In addition, Sponsors are strongly involved in capstone by providing a project for which a product is expected, having a committed company liaison with the student team, having guaranteed IP ownership, and covering a sponsorship fee. Details and results are provided in the remainder of the paper, along with challenges and areas where improvements are being pursued.

Table 1. Growth of KU-ME senior design sequence

Year/Semester	Model 1a	Model 1b	Model 2b	Model 2c
Fr. (1^{st} sem.)	- - - - -	- - - - -	- - - - -	Cornerstone-A CAD – Proj. w/Programg. Team
Fr. (2^{nd} sem.)	- - - - -	- - - - -	- - - - -	Cornerstone-B Programming – w/CAD Team
So. (1^{st} sem.)	- - - - -	- - - - -	- - - - -	- - - - -
So. (2^{nd} sem.)	- - - - -	- - - - -	- - - - -	- - - - -
Ju. (1^{st} sem.)	- - - - -	- - - - -	- - - - -	- - - - -
Ju. (2^{nd} sem.)	- - - - -	- - - - -	Capst2b-1 (design process)	Capst-prep (design process)
Se. (1^{st} sem.)	- - - - -	Capst1b-1 (design proc. + fac. proj.)	Capst2b-2 (spon. or fac. proj.) 1^{st} or 2^{nd} sem.	Capst-A (sponsored project – first half)
Se. (2^{nd} sem.)	Capst1a-1 or Capst1a-2 (design proc. + fac. proj.)	Capst1b-2 (design proc. + fac. proj.)		Capst-B (sponsored project – second half)

2 Capstone Course Sequencing

When developing and planning the overall design experience for undergraduate students, there is a wide variety of models to consider – each having benefits and associated challenges. One of the model-types to consider is the number and organization of capstone courses (and credit hours): delivered sequentially and/or in parallel. The "design" of the capstone experience is much like the actual capstone experience itself – there is no "best" solution, so an optimal solution is sought; and these solutions vary among institutions. Although ABET is sometimes credited with driving such decisions/practices in engineering education, it is actually the educational institutions and the professional societies which are working toward the "best" engineering graduate and having the "best fit" for industry positions.

Capstone course sequence combinations that have been employed can be broken into two major Models: (1) integrated incorporation of both the teaching of the “design process steps” and a realistic “project experience”; and (2) separation of “design process steps” from the “project experience”. Each of these major categories has been implemented using one of the following:

a. One course
b. Two courses
c. Three courses (sequential and/or parallel)
d. Four courses (sequential and/or parallel)

Over the past 25 years, Mechanical Engineering at the University of Kansas (KU-ME) has used Models 1a, 1b, 2b and 2c (see Table 1). During that time period, many educational institutions have also modified their capstone experiences in order to meet changing needs and demands. So, from that point-of-view, KU-ME is not different. However the final resulting outcomes appear to be different from those of most institutions.

KU-ME first had two capstone courses, of which students needed to enroll in only one (Model 1a). Later, we required students to take both courses (Capst1b-1 and Capst1b-2). In combining the “how to” with the “project”, these early courses employed faculty-initiated projects with faculty-determined requirements. Thus, the greatest drawback was that students did not always have the [realistic] types of projects that they might encounter when employed as engineers, nor did they have demands from those who wanted “products” as opposed to those who wanted “learning”. Neither of these “wants” is “bad”; but, within reason, the best experience for student preparation should include an outstanding final project outcome, coupled with deep student learning. An important secondary difficulty with Model 1 was that, at the outset, students need to know how the whole design process should proceed, in order to plan appropriately and to designate tasks appropriately for the “project experience”. Thus, students often “floundered” as to knowing the overall direction that a project should encompass. This is not necessarily a negative from an educational point-of-view; but would be serious from a sponsor’s point-of-view. Obviously, once students have completed one of these processes, overall direction should not be as significant of an unknown for following projects.

Thus, about 15 years ago, KU-ME adopted Model 2b (Table 1). The reasons for using this model were that: (1) in the first course (Capst2b-1), students could be exposed to as great a variety of design steps and issues as reasonably possible – for we fully knew that, in all probability, the actual capstone project in which they became involved would include only a limited number of design steps and issues; and (2) knowing the overall design process allows much better planning for the “real” capstone project. But a major goal of educational institution is “learning”, and only using the design project by itself would not effectively accomplish that goal from the wide-ranging-exposure perspective. Thus, Capst2b-1 provided that wide-ranging learning perspective, while Capst2b-2 allowed students to see first-hand the application of several of the design steps and issues. Even though not seeing all steps/issues in that project, students would have dealt with a “real” problem and also know that there were many other possible issues/paths to a solution and final product – yielding better overall preparation for the engineering work world.

For Capst2b-1, KU-ME went with only faculty-developed example projects, so that students could see some applications of the design process, not just the “theory”. For Capst2b-2, KU-ME went with a mixture of faculty-driven and outside sponsor-driven (by national competitions, industry, non-profits, and inventors) projects. Regarding Capst2b-1, students did not appear to learn the desired processes as well as anticipated. They did not feel that the example projects were as relevant as could be; so much of their feedback was focused on the relevance of what they deemed to be “academic exercises”, even though they did learn the diversity of design steps/issues that was possible. Capst2b-1 later became Capst-prep (terminology explained below and in the Nomenclature); so modifications of the course are detailed in the discussion of Model 2c.

Regarding Capst2b-2, there was still a significant difference between the experiences of teams that dealt with faculty-initiated projects and those who dealt with outside-sponsor projects. It soon became apparent that the outside-sponsor projects provided a much broader experience, in that teams really learned how to work with external Sponsors who want marketable products (or products which helped them manufacture or assess marketable items). In addition, it was also apparent that, with a single project development course, there was just not enough time for students to progress reasonably through the design process and spend sufficient time on all of the steps involved.

Thus, seeing the same issues as explained by Pettiford (2014), KU-ME independently adopted Model 2c three years ago (Table 1). (Note that the naming convention was changed for Model 2c because this is KU-ME’s current model, and these courses will be referenced extensively in the following.) In this model, Capst-prep covers as many different facets of the design process as possible. This prepares students well for the capstone project of Capst-A and Capst-B, while also exposing students to steps/processes which they may not experience in that two-course capstone project. The two-course capstone sequence of Capst-A and Capst-B allows about nine months for the students to cover the entire design process – at least through delivery of a product [plus documentation] to the external sponsor. Other programs have found that Sponsors are not willing to wait nine months for a good solution to their problem (Hackman et al. 2013), but KU-ME has found that, if Sponsors are vested in the academic/industry partnership, they are quite willing to wait. Regarding industry versus faculty sponsorship, KU-ME has rare cases [projects] which are faculty sponsored; these are for students whose career directions are headed into graduate degrees. These few projects are usually directed toward research topics.

Model 2c has been the most rewarding for the students and for the faculty involved in capstone courses. This model includes coverage of all of the design process facets that KU-ME faculty feel are important in the first fundamental course, Capst-prep. Capst-prep allows students to see the design process in total, so that they are well-prepared for applying, planning and executing that process with regard to their capstone project in the following two-course sequence (Capst-A and Capst-B). In addition, those next two courses generate company Sponsor excitement because student teams have a firm basis in design which yields better project final products, and gives Sponsors opportunities to hire promising team members for their companies.

(Note that, in order to accommodate "off curriculum sequence" students, all three capstone courses are offered in both the spring and fall semesters. Thus, a student can start the sequence in any semester at KU-ME).

Capst-prep includes a once-a-week lecture followed by an intensive lab session in which students interact with each other, other teams, class assistants, and the instructor to learn in real time, what needs to be done – what is difficult, what is easy, what needs careful attention, what steps to take in approximately what order, what not to do, etc.

As stated in the discussion of Capst2b-1, termed KU-ME's Capst-prep in Model 2c, students had concerns with the relevancy of Capst-prep projects. This feedback resulted in modifying the course projects used in Capst-prep. The first modification was to use old capstone projects. These were real projects from company or inventor Sponsors; but the instructor and teaching assistants fielded Sponsor questions, since the original Sponsors were no longer involved. Students liked these better than the faculty-developed projects, but still felt that these were "less real" because they'd already been solved; and the original Sponsors couldn't be asked about the directions chosen. The second modification was to have the Capst-prep teams work with current capstone teams on current projects (in Capst-A) – working on an "add-on" part of a project, which was not the main focus, but, if solved, could add some value to the final product. In these cases, students appeared to appreciate the projects better. However, because the capstone teams had gone deep into their projects by the time that Capst-prep students became involved, those students seemed to feel that, since their projects weren't the main focus and they were not leading the overall project, there was less value for their teams and certainly less importance placed on their teams. So student "buy in" was less of an issue than it had been, but was still an issue. The third modification was to have the Capst-prep teams select projects which had direct relevance to them, making a major decision in their lives – such as making a major purchase or making a major career decision. These decisions can use many of the steps and end up addressing many of the issues that occur in the design process. In this case, students took these projects more seriously and were well invested in the process. However, such projects are driven entirely by the students (no outside Sponsors) and thus do not include many of the crucial decisions/steps needed in an engineering design process. Thus Capst-prep is still evolving in order to best reach the students while, at the same time, helping to optimize their knowledge of the design process, from both overall and detailed points-of-view.

In Capst-A, teams are selected and matched with projects. The teams then apply relevant premises from Capst-prep to their projects, to the point of having completely [theoretically] tested their designs, having them ready for fabrication (or programming, if required). Capst-B picks up from the Capst-A with fabrication (or programming – for coding projects) through delivery of the product (which includes complete documentation) to the Sponsor.

KU-ME also has a modified Model 2c, wherein Capst-prep and Capst-A run concurrently. This is for students whose academic careers would be extended one semester, with only the one course (Capst-B) needed to complete their last semester. This modification has been relatively successful; but still, teams following this plan are found to be somewhat handicapped by not having seen one complete design process prior to starting their capstone projects. On the other hand, even though most students indicate that they would prefer the strictly sequential three-course plan, some students also state that it's valuable for them to see the process steps (Capst-prep) at the same time that they are going through the first capstone course (Capst-prep). However, these students also strongly state that it is best for Capst-prep to be separate from Capst-A and Capst-B, and do not think that combining Capst-prep with the other two courses would be beneficial.

3 Industry Sponsorship

3.1 Background and Rationale

It has become increasingly clear that industry sponsorship is requisite in the fast-changing landscape of the engineering capstone experience. From 1994 to 2005, the use of industry sponsorships for engineering capstone projects increased from 59% of engineering programs in the United States to 71% of U.S. programs (Howe 2010). Anecdotal evidence indicates that this trend has continued to the present day, for a variety of reasons.

Providing pertinent, closer to "real world" projects for engineering capstone students is of great importance if students are to have a relatively genuine, engaging experience that will illustrate to them the nature of their future experience(s) as engineering employees in industry (DeAgostino et al. 2014). On average, only an estimated 20% of engineering undergraduates in the United States continue directly to graduate school without first working as engineers in industry (Anderson-Rowland and Rodriguez 2015). This points to the fact that engineering education should continue to tailor itself to make most of its graduates work-ready, instead of research-ready; research-ready usually being an individual student preference/selection. Industry sponsorship of capstone has greatly helped to make more engineering undergraduates work-ready at KU-ME.

The typical reasons cited for seeking industrial sponsorship of capstone projects remains consistent (Howe 2010):

- Provide students with realistic projects
- Project expectations are higher (among students and faculty) when there are customers who need results
- Students garner experience working in an industry environment
- Students are exposed to potential employment opportunities

Going a step beyond these typical reasons, there are emerging trends in higher education that are changing the terms of why industrial sponsorship is required.

Excluding research funding, higher education funding in the U.S. has been steadily decreasing over the last 15 years (Pew Charitable Trusts 2015). Capstone collaboration with, and sponsorship by, industry represents an additional, alternative revenue stream for many programs. While capstone sponsorship fees vary widely from zero to upwards of $40,000 (Howe 2010), charging sponsorship fees can be justified for a number of reasons:

- Provides “creative tension” and heightened expectations among students and faculty
- Promotes deeper “buy-in” from Sponsor/Customer
- Funds administration of dedicated capstone programs and personnel
- Funds stipends for participating faculty advisors
- Funds growth of department and programs through acquisition of materials, software and equipment that are needed for positive capstone outcomes

In addition, KU-ME’s funded capstone model promotes sponsorship as a *partnership*. Companies benefit not only from getting actual engineering work done, but also by gaining access to students as part of a more organic talent pipeline. Capstone projects can serve as “extended interviews”, much in the same way as cooperative employment and internships. The deeper interaction with faculty can also lead to further collaboration and research agreements that can address and satisfy the growth needs of sponsoring organizations.

Establishing these more organic relationships (spurred by greater buy-in on both sides) also benefits faculty more broadly. As faculty are remunerated for participation, they too become vested stakeholders, and gain current, relevant experience in industry. Faculty can be reluctant to participate in projects where they do not have major control over the outcomes, but industry-related experience and remuneration help to provide “creative tension”, whether welcome or not. Establishing reasonable (but significant) capstone fees provides mutual benefit to sponsoring organizations, academic engineering institutions, faculty, and students.

3.2 Capstone Model with Industry Sponsorship

The model for capstone with industry sponsorship at KU-ME is well defined and has been vetted by University Administration and Legal Staff. The primary parameters are:

- $7000 sponsorship fee; exempt from all University indirect charges (no overhead)
- Two semester duration (Fall/Spring or Spring/Fall)
- Two students minimum; three is typical. However, up to five can be assigned if complexity dictates. If more than five students are required, Sponsors are very strongly encouraged to fund multiple teams
- All IP is retained by the Sponsor

Retention of IP is a primary parameter of importance to Sponsors. While this deviates from the typical norm at many research universities (Dozier and King 2012), KU-ME has found that it is imperative that the Sponsor be assured of this. This arrangement is in place to encourage companies to sponsor, interact, and share information with the University. If this parameter were not in place, many companies (especially start-ups) would be reluctant to collaborate fully – and, as could be expected, this could significantly reduce the number of Sponsors, and negatively impact the quality of the student (and faculty) experience. All Sponsors are provided with signed non-disclosure and confidentiality agreements by participating students and faculty. For the students, this arrangement also serves to simulate working as an engineer at a typical company, where IP is usually retained by the employer.

In terms of promoting deeper engagement and partnership, the sponsoring organization is asked to appoint a liaison to work with the student team. This is of the utmost importance to ensure that the student teams can get information and feedback in a timely manner. Much of a team's success hinges on the depth of engagement of the liaison. A working-level engineer is usually better suited for this role than a member of engineering management. It should be noted that in order for collaboration to be successful, support is required from the Sponsor at all levels of its organization: top, middle, and working level. However, it does not make sense to have members of middle or upper engineering management function as liaisons, since they typically do not have the time, nor the information required by the team, to result in a successful project outcome. Collaborative buy-in at all levels of the sponsoring organization assures that everyone is vested in the success of the project. This is an important component of promoting sponsorship as a "partnership".

Some literature indicates that there may be issues with outside Sponsors being heavily committed to capstone and the associated projects (Pezeshki and Beyerlein 2015). KU-ME has found that Sponsors are much more involved and vested [stakeholders] in their projects when there is a strong company liaison, when the company invests a small but non-trivial amount of funding, when there is clear opportunity to "try out" students for future new hires, and when the company owns any IP generated by the project being sponsored.

KU-ME's project management structure is configured in such a way as to ensure a realistic simulation, as well as providing student teams with the necessary resources to assist with their success. Each team is assigned an industry-experienced (preferably 10+ years) faculty member as a project manager, and a subject matter expert faculty member as a technical manager. Along with the Sponsor's liaison, this serves to simulate a matrix-management organization, so common in modern companies, that 84% of surveyed workers report that they work in a matrix organization (Bazigos and Harter 2016). Although it is sometimes difficult for student teams to report to "multiple bosses", it gives them invaluable experience in dealing with this real world situation.

Aside from simulating a matrix management style organization, multiple mentors/managers also ensure that the student teams can get information and guidance they need, in a timely manner. Student teams are expected to meet with both the project manager and technical manager on a weekly basis to track progress and get issues resolved as quickly as possible. By meeting separately with each, they can also ask candid questions and be forthcoming with issues they may be having. Meetings with the liaison are flexible, based upon the company's needs and preferences; but formal meetings with the sponsoring organization are expected at least twice per semester, with informal interaction (e.g., phone calls, emails, and informal face-to-face meetings) occurring on a more regular basis, typically weekly or bi-weekly.

Finally, it should be noted that the Sponsor may be unfamiliar with how to manage collaboration with a student team; so the Sponsor may need guidance and support throughout the project. In this regard, it is typical for the project manager (industry-experienced faculty member) to take the lead in working with the Sponsor.

This points to the need to have this faculty member dedicated to the capstone curriculum, both from the standpoint of cultivating sponsorship, and directing the program academically.

3.3 Project Management

As part of the tracking and management of each project, as stated previously, two faculty members are assigned to each project. A faculty member with background and expertise in the technical aspects of the project, and an industry-experienced faculty member with project management experience. The previously described weekly meetings among the two faculty members and the team are critical for achieving proper focus on different aspects of the project.

The technical manager (faculty member) assists the student teams with research methodology, advice on where to look for technical information and support, and, to a lesser extent, managing the progression of the project. If the technical manager has the background knowledge, s/he can directly advise on the technical aspects, helping the teams to avoid obvious pitfalls with specific assumptions and methods.

The technical manager also reviews presentations and reports made by the student team, and provides feedback to the team. S/he attends all project reviews with the other managing faculty member and the Sponsor. The technical manager provides grade input for the student team, but is not ultimately responsible for student grading.

The project manager (industry-experienced faculty member) actively oversees the progression of the project, and, to a lesser extent, assists with technical issues when appropriate. The project manager also assists the team in determining appropriate and necessary Customer (Sponsor) interaction. Since the project manager has experience working with and managing teams, s/he can also help to mediate group dynamics, division of labor, and guide the groups in the application of inter-personal professional skills.

Like the technical manager, the project manager also reviews presentations and reports made by the student team, and provides feedback to the team. S/he attends all project reviews with the technical manager and the Sponsor. The project manager assigns grades, and makes decisions to accommodate Sponsor demands, and project direction. As the faculty member who has typically established a relationship with the sponsor, s/he becomes, de facto, the lead manager.

As noted, the two faculty members meet with the team separately (part of this is pragmatic; the project manager meets with many teams, and scheduling conflicts cannot be avoided) to assure that each faculty member can guide the team as s/he sees fit. The two faculty members meet periodically to discuss the team's progress, especially at reviews and presentations, and on an ad hoc basis as necessary. As with the management of all projects, good communication is key. This communication and feedback between the two faculty members must be assured during the project. It is important that these meetings between the two are set up and adhered to so that both faculty members are in agreement with how the project should proceed. Failure to do this can result in students taking the easiest route by selectively accepting faculty member input.

3.4 Conflicting Direction and Ambiguity

Since the student project teams essentially have two managers, at times they receive conflicting direction on how to approach the project. Sponsor/Customer demands may exacerbate this condition of conflicting direction. This issue must be addressed with the students by their faculty managers. Encouraging students to work through and resolve this ambiguity, on their own, systematically and with appropriate support, leads to better prepared engineering undergraduates (DeAgostino et al. 2014). If the appropriate hands-off approach is taken, only the student teams will have sufficient knowledge of their resources and possibilities to select the best foreseeable path. Students have essentially four possibilities for seeking advice and information:

1. Project Manager Direction (Industry-Experienced Faculty Member)
2. Technical Manager Direction (Faculty Technical Expert)
3. Sponsor/Customer Liaison Direction
4. Unique Project Knowledge that Only the Team Possesses from Other Relevant Sources

This approach encourages critical thinking skills that weigh various options, and requires synthesis of all information the team has received, from multiple sources. Some of this information may be anecdotal at best, leading to further ambiguity. At times, the team alone must determine the best apparent path for the project, in spite of what they may be told to do by the faculty members and/or Sponsor.

This additionally helps the team and each member to develop the distinction between when they should do exactly as they are told, and when they must allow knowledge that they alone possess to dictate their (best) actions. There are of course times when one individual must make a final decision. In order to ensure that the (reasonable) demands of the Customer/Sponsor are met, the project manager has final say. But s/he only exercises this authority when absolutely necessary, because it is generally best to allow the team to follow some non-optimal paths in order to learn for the future.

Since many students in the U.S. appear to have become accustomed to an educational system that encourages a single (correct) method for engineering problem solving, students may struggle with, or even outright reject, these conflicting and ambiguous situations. Engineering students have been generally taught to solve short-time-period problems with single, correct solutions. Having multiple bosses, various possible methods for problem solution, and no single correct answer, confounds students (indeed, even some faculty may have difficulty with this). These types of experiences serve to teach students that there is always more than one way to solve a problem, and encourages them to be what industry refers to as "self-starters".

The concept of being a "self-starter" is frequently posted in position descriptions by many companies. The ambiguity and conflict that comes with determining project direction helps to build this enigmatic skill. If we rephrase "self-starter" as one who possesses inquisitive initiative, we are expecting students to question and explore on their own, and then make decisions that move a project forward based upon results of that inquiry. Being a "self-starter" is embodied in the ability to have and sustain inquisitive initiative (Bell-Huff et al. 2016).

In summary, students must be repeatedly encouraged to persist, even in the face of ambiguous, conflicting, and confusing information that frustrates. They must be further encouraged to allow a best situational solution to present itself, rather than rushing to (or requesting) a quick solution.

4 Challenges for KU-ME

In a rapidly changing world, no capstone program can remain stagnant, utilizing only what has worked in the past, especially as new challenges continue to emerge. KU-ME is continuing to consider ways to better address several significant challenges. These challenges include adequate Sponsor engagement, adequate student engagement in the Capst-prep course, and increasing the educational support of students so they can better address issues of conflicting direction and ambiguity in their capstone projects.

As discussed previously, KU-ME engages Sponsors in a way that treats them as partners. Many Sponsors, especially first time Sponsors, have difficulty understanding how to respond well to, and engage adequately with, their sponsorship. KU-ME continues to work with Sponsors on the following:

- Identifying a working level engineering “point person” to work with project teams on an on-going, informal basis (liaison/mentor)
- Responsiveness to project teams’ questions, concerns, and needs
- The ability for Sponsors to view themselves as partners, and understanding what exactly that means

A consistent, tenacious approach to addressing these sponsor challenges is being employed. Not all Sponsors are a good “fit” for this type of engagement, so finding the “best fit” Sponsors for this type of engagement is also a component of addressing these sponsor challenges.

Similarly, student engagement in the Capst-prep course remains a challenge. As detailed previously, multiple project sources and arrangements for the Capst-prep course have been utilized, with varying degrees of success. The challenge remains in identifying the optimal balance between the “reality” of the projects, student buy-in to the projects, and ensuring the Capst-prep projects meet the learning objectives required to support the capstone sequence well.

The third significant challenge faced by the KU-ME capstone program is adequately educating students to deal with conflicting direction and ambiguity. Some senior engineering students are still surprised (even angry, intimidated, etc.) by the fact that there is not necessarily one, correct answer for their project.

By addressing conflicting direction and ambiguity in earlier courses (including the freshman level introductory project sequence, and the Capst-prep course), KU-ME is working toward equipping students to better respond to conflicting direction and ambiguity. The challenge of adapting students to operate in an ambiguous environment remains on-going, especially when a substantial amount of their education has reinforced the idea that there is one correct answer.

While these and other challenges do remain, diligence and flexibility in addressing them in a rapidly changing world is the key to dealing with them, if not overcoming them. Challenges in capstone implementation will always remain and evolve. Capstone programs, like KU-ME's, need to continuously and persistently identify those challenges and modify their approaches to adapt to them.

5 Conclusions

We have found that a three-course capstone sequence works quite well in giving students wide exposure to the overall design process (first course – Capst-prep) while also giving them very specific experience (second and third courses, Capst-A and Capst-B) on externally sponsored industry projects. These two components provide firm design fundamentals coupled with applications that are quite similar to those which students will encounter as engineers in a work environment. Issues remain with helping students adequately understand, and relate to, the concepts covered in Capst-prep. This means that Capst-prep will continue to evolve as we work to optimize its student-perceived impact.

Crucial to this three-course capstone arrangement are externally supported projects with strongly vested Sponsors who provide committed company liaisons. Needed in addition is a university management structure which (at least) includes a project managing faculty member for overall features of each project, and a technical managing faculty member who is committed to assuring that fundamental engineering principles are solidly applied and results accurately interpreted. With the student teams required to balance the demands of the two faculty members and the Sponsor's liaison (along with the teams' independent findings, in the process of developing relevant worthwhile solutions and products) this arrangement provides students with a quality experience which is much like that found in a company's engineering environment. While it is clear that the academic experience cannot exactly replicate the industry experience, this arrangement makes every effort to achieve sufficient similitude.

Future efforts will be directed toward enhancing the engagement of Sponsors, seeking those who most want to, and understand what it means to, be a partner. In addition, adjustments to Capst-prep and support of student adaptability to ambiguity will be emphasized in order to further enhance student capstone success.

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The Content and Structure of Code of Ethics for Engineers in China

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Abstract. Code of ethics for engineers are basic principles of professional conduct. Professional engineering associations in different countries have different code of ethics. This study reviews the content and items of code of ethics in various professional engineering associations. It also conducts an empirical research in China to examine the content and structure of the code of ethics for Chinese engineers. The findings indicate that the code of ethics for engineers consist of four dimensions, i.e. “professional attitudes”, “professional characteristics”, “professional beliefs”, and “professional responsibility”. Using various analyses on rated importance level of ethical code items, the paper reveals a statistically significant difference in selecting items of code of ethics between engineers in the industry, and university faculty who teach ethics training courses.

Keywords: Code of ethics · Content and structure · Engineering education · China

Nowadays, high and new technologies, such as the internet, genetic engineering and nuclear energy empower engineers to promote the well-being of mankind to a great extent. However, due to improper human engineering practice, engineering technologies also bring a lot of problems such as environmental pollution, resource exhaustion, and ecological imbalance. It is no exaggeration to say that all projects have a relationship with ethics in the world (Li 2006).

Engineering ethics are meant to describe and analyze the relationship between the engineering industry (including the activities and results) and the outside world (Zhu 2015). Code of ethics express the collective commitment of professions to ethics. As conduct codes, they intangibly affix a moral obligation to the relevant professional members in professional practices. They also remind and guide practitioners to pay attention to the problems about society and stakeholders’ interests while working. During the construction of engineering ethics, ethical codes become the guide and lighthouse to enlighten our way to move forward.

This paper examines the content and structure of code of ethics through literature review and empirical research.

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1 Review on Code of Ethics for Engineers

1.1 Code of Ethics of Engineering Associations in China

There are more than sixty engineering associations in China, including China Civil Engineering Association, China Water Engineering Association, Chemical Industry and Engineering Society of China, China Computer Federation, and Chinese Mechanical Engineering Society, etc. The Chinese Mechanical Engineering Society (2011) puts emphasis on "people-oriented and the pursuit of social welfare in its regulations and objectives". Chinese Society of Agricultural Machinery (2015) makes a point in its regulations and objectives that "ethics should put emphasis on improving the construction of scientific morality, advocating and implementing the principles to benefit the humankind and serve the society with scientific researches. Furthermore, it should resist any scientific research that violates scientific morality and ethics, safeguard the dignity of the science, and say no to any behavior that violates the scientific community practice such as counterfeiting, plagiarism and falsification". The regulations of Chinese Society of Electrical Engineering (2014) state that "ethics should stick to and develop the matter-of-fact scientific attitude and the good learning style, being against every kind of scientific misconducts; respect the labor, knowledge, talents and morality of creation, and advocate the spirit of dedication, innovation, truth seeking and cooperation". Chinese Society of Agricultural Engineering (2012) puts forward "abide by social morality, advocating scientific morality, honesty and self-restraint in its regulations and objectives". Chinese Society for Internal Combustion Engines (2010) mentions "scientific truth-seeking, sustainable development, advocating devotion, innovation, truth seeking and cooperation in its regulations and objectives". Chinese Hydraulic Engineering Society (2009), Chinese Association of Refrigeration (2014), Chinese Vacuum Society (2014), China Instrument and Control Society and Chinese Association of Automation (2013) all put forward "advocate the spirit of dedication, innovation, truth seeking and cooperation in their regulations and objectives".

"Creeds for engineers" is put forward by the institute of engineers in Taiwan. Four responsibilities are mentioned in the Creeds. The first creed mentioned is an engineer in the community's responsibility: law-abiding dedication and respect for nature. The second is the engineer's professional responsibility: dedication, innovation and progress. Third, the responsibility of engineers to employers: sincere service and mutual benefit. Fourth, the responsibility of engineers on the colleagues: division of labor and pioneering.

From the regulations of these engineering associations, it shows that most engineering associations lack detailed standards in the professional codes for engineers, it is clear that most associations do not have professional ethics codes specially designed for engineers. Professional ethic for engineers are usually carried out through the associations' regulations. The typical expression are generally such as, following social public orders and legal systems, serving the social construction with professional skills. But there are no relevant standards for social public interests and eco-environment protection (Su and Cao 2007). Most of the regulations of Chinese engineering associations are standards and requirements for association members on their scientific research, few of which are ethical codes and guidelines in engineering practical activities.

1.2 Code of Ethics of Engineering Associations Abroad

With a review on code of ethics for engineers from different associations, it was found that the first ethical guideline for engineers of almost all the associations was "hold paramount the safety, health and welfare of the public".

The code of ethics of the World Federation of Engineering Organizations (WFEO) include four dimensions of the demonstration of integrity, competent practice, exercise of leadership, and protection of the nature and environment. To be more specific, the codes include rejecting from fraudulent, corrupt or criminal practices, objective and truthful attitude, careful and diligent manner, enhancement of the body of knowledge, etc.

The National Society of Professional Engineers (NSPE) is the only organization that advocates for the national licensed professional engineer, whose ethical codes were revised newly in 2007, including honesty, impartiality, fairness, equity, professional competence, objective reality, trustworthiness, responsibility, legitimacy, etc.

The ethical codes that American Institute of Chemical Engineers (AIChE) have passed in 2015 includes protecting the environment, keeping secrets, formally advising employers or clients, taking responsibility, accepting advice with an open mind, merits of services, respecting colleagues/partners, rejecting harassment, conducting themselves in a fair, honorable and respectful manner, etc.

With a long history of over 150 years, the American Society of Civil Engineers (ASCE), the oldest national society of professional engineers and now the leader of global civil engineering, established the code of ethics for members in 1914, which were revised in 2006, to include sustainable development, competence of work, objective, truthful, honest, neutral, trustworthy, fair, white-handed (not offering or accepting bribes), etc.

Institute of Electrical and Electronics Engineers (IEEE) is the world's largest technical professional organization. There are more than 420,000 IEEE members in over 160 countries. Its code of ethics include avoiding real or perceived conflicts of interest, stating claims or estimates honestly and realistically, rejecting bribery, maintaining and improving the technical competence, and treating all persons fairly, etc.

Engineers Australia (EA), the largest and most diverse professional body for engineers in Australia, code of ethics' frame is similar to that of WFEO. The four dimensions include well-informed conscience, honest and trustworthy, respect of all persons, development of knowledge and skills, honest and effective communications, etc.

Japan Society of Civil Engineers (JSCE) was established as an incorporated association in 1914. JSCE's code of ethics were newly revised in 2014, to include respecting both the nature and the fabric of civilization and culture, ensuring the security of society and mitigate disasters, fulfilling their professional responsibilities, guarding the integrity and avoiding any conflicts of interest, striving for self-improvement, etc.

1.3 Scholars' Perspectives on Code of Ethics for Engineers

Mike Martin, an American scholar, pointed out in 2007 that engineering ethics would introspect all the key problems in the globalized economic era centered on the technical development. Among the key problems would be the environmental issue that is, to request engineers to protect the environment.

Charles (2013) believed that the past code of ethics have paid less attention to public service and security. In the past decades, however, most code of ethics paid more attention to the security and the public health as the public were having more and more evaluation and awareness of the engineering products and device safety. They even regard environment protection as the most important responsibility for engineers.

By comparing and analyzing the engineering ethic codes of Institute of Electrical and Electronics Engineers (IEEE) as well as other thirty-two countries and regions, AlZahir and Kombo (2014) found that four countries and regions had code of ethics consistent with IEEE, while the code of ethics in other twenty-eight countries were more or less different. The 6, 4, 1, 9 and 10 articles of the IEEE engineering ethics codes rank the top five mentioned by most countries and regions, respectively adopted by 27, 25, 24, 23 and 22 countries. These five articles are: to maintain and improve our technical ability; to reject bribery in all its forms; to accept responsibility in making decisions consistent with the safety, health, and welfare of the public; to avoid injuring others, their property, reputation, or employment by false or malicious action; to assist colleagues and co-workers in their professional development and to support them in following this code of ethics.

Scholars in China also pay great attention to engineering ethics. Ning and Hu (2007) believed that the principles of engineering ethical universality include “to be oriented at people, to care for the lives, to be safe and reliable, to love the nature and to be fair and just”. Li (2008) believed that engineering ethical standards include efficiency, safety, loyalty, honesty, responsibility, etc.

Tang (2007) believed that the two basic principles for American engineering ethics were honesty and responsibility. Standards of honesty in engineering are relatively high, higher than the honesty requirements for day to day life. Requirements for honesty in engineering are the result of the inside and outside combined engineering practice expectation. The public-welfare features of engineering are different from the commerce and individuals. Honesty can promote the cooperation and trust required in the engineering practice. Meanwhile, the cooperation between science and technology make the principle “honesty” more important. From the perspective of engineers, individual responsibilities include the safety, the professional, the environment and the global/international responsibilities.

Zhang and Yao (2014) made a detailed presentation of the ethics codes which engineers must follow in various engineering activities. For instance, code of ethics in the engineering research include: to be honest, upright without fraud; to respect the intellectual properties of others without plagiarizing others’ work achievements, and humanitarianism. Code of ethics in the engineering manufacturing and building industry mainly include: manufacturing or building products legally; integrity; humanitarianism; diligence and loyalty. Code of ethics in the engineering experiments include: honesty and integrity; diligence; humanitarianism and loyalty. Code of ethics related to commerce include: integrity, humanitarianism, justice, loyalty and diligence. Code of ethics for taking social characters in public affairs include humanitarianism, integrity, fairness and justice. In conclusion, humanitarianism and integrity are prerequisite code of ethics required for the engineers in each engineering field.

Li et al. (2016) had a viewpoint in the new book Engineering Ethics that the first responsibility principle was the obligation of safe, sustainable development, loyalty and public exposure. Meanwhile, the professional virtues of engineers include reliability, honesty, responsibility, and faithfulness.

Based on the literature reviews, it is obvious that the publication and implementation of engineering ethical standards in Chinese Mainland are relatively weak. Various engineering associations and organizations put less attention on the study and formulation of code of ethics. As discussed above, there are some similarities of code of ethics between home and abroad, but in China some study on code of ethics are non-empirical and few survey was carried out. This study try to make some investigative analyses and evidence-based researches on the content of code of ethics in China.

2 An Empirical Study on Code of Ethics for Engineers in China

2.1 Methodology

Based on previous researches, this paper has made a summary and generalization of these opinions according to the actual situations, revised and improved the original code of ethics, generalizing and selecting twenty-five items to be the foundation for the preparation of questionnaires. The twenty-five items included: hold paramount the safety, health and welfare of the public; be supreme to the employers; prevent the distortion of professional judgment; be safe, reliable and responsible for others; be prudent and diligent; be honest; reject bribery in all its forms; respect everyone; cooperate with each other; be responsible for your own behaviors, etc. Questionnaires on the code of ethics for engineers were prepared to figure out the evaluation on the guidelines listed. The investigated samples were selected from the university faculty and engineers. On the one hand, it was to know about the evaluation of engineer educators on code of ethics; on the other hand, it was to know about how the engineers in the front line of engineering practice look upon the code of ethics. Different items were established in the personal information according to different respondents. Likert Five-point Scale was adopted. From 1 to 5, it stood for "not important" to "important", requiring the respondents to make selective judgment on the importance of each guideline using five grades. Meanwhile, respondents were requested to select five items that they regarded as the most important from all the listed guidelines in the questionnaire and prioritize them in terms of importance from high to low.

Questionnaires for university faculty were filled with on-site guidance and were immediately collected. 150 questionnaires were sent and 135 were collected. Questionnaires for engineers were directly sent and collected via the cellphones. 206 questionnaires from cellphones were recycled. Finally, 205 effective questionnaires were determined from the two groups. The total effective recycling rate was 58%. For more detailed description of survey samples, see Table 1.

Table 1. Description of survey samples (N = 205)

University Faculty (N = 105)			Engineers (N = 100)		
Variable	Group	Frequency	Variable	Group	Frequency
Gender	Male	53	Gender	Male	73
	Female	52		Female	27
Age	≤ 25	4	Age	≤ 25	17
	26–35	34		26–35	63
	36–45	35		36–45	16
	46–55	29		46–55	3
	≥ 56	3		≥ 56	1
Type of institution	Project 985 universities	36	Professional title	Technician	10
	Project 211 universities	36		Assistant Engineer	35
	Ordinary university	33		Engineer	39
				Senior Engineer	14
				Professor Engineer	2
Identity	Faculty	75	Engineering field	Civil Engineering	49
	Researcher	3		Hydraulic Engineering	18
	Administrator	20		Chemical Engineering	3
	Graduate Student	5		Information Engineering	20
	Others	2		Environmental Engineering	7
				Biomedical Engineering	3
Years of teaching ethics or related	0	39	Years of working	1–2	18
	1–2	22		3–5	25
	3–5	16		6–10	27
	6–10	16		11–15	17
	≥ 11	12		≥ 11	13

2.2 Results and Discussion

2.2.1 Four Dimensions of Code of Ethics for Engineers

In order to investigate the structure of code of ethics for engineers, this paper first conducted exploratory factor analysis based on the survey data of 25 items in the code of ethics for engineers. Before making the factor analysis, all the survey data were checked to ensure that they were suitable for factor analysis. The judgment standards are usually KMO value and Bartlett's sphericity test Chi-square value. Ordinary standards for factor analysis are at least above 0.6. According to the KMO and spherical Bartlett test on all the effective data, the KMO coefficient for the survey

Table 2. KMO and Bartlett's test

Kaiser-Meyer-Olkin measure of sampling adequacy		.881
Bartlett's Test of sphericity	Approx. Chi-Square	1264.183
	df	136
	Sig.	.000

samples was 0.881. As is shown in Table 2, it represented that common factors exist among variables and the items were suitable for factor analysis. Furthermore, Bartlett's sphericity test Chi-square value was 1264.183. The significance level was that $P = 0.000 < 0.05$. Significance was reached. Hypothesis that relevant matrixes were not cell matrixes is rejected. The Table 2 showed that survey data were suitable for factor analysis.

In the exploratory factor analysis 205 effective questionnaires were acquired during the sample survey, PCA (principal component analysis) was adopted and common factor orthogonal rotation was carried out with varimax rotation.

Table 3. Factor analysis results

Content	Rotated component matrix			
	Factor 1	Factor 2	Factor 3	Factor 4
A24 Be more dedication	**.749**	.115	.201	−.002
A25 Seek for truth in science	**.737**	.176	.201	.162
A21 Innovative spirit	**.688**	.316	.066	.031
A20 Develop professional competency	**.657**	.171	.162	.316
A18 Abide confidential rules	**.604**	.274	.019	.228
A17 Perform services only in competence areas	**.565**	−.011	.203	.165
A7 Be impartial	.097	**.783**	.362	.112
A6 Be honest	.171	**.766**	.240	.067
A8 Be loyal and reliable	.339	**.728**	.029	.189
A9 Reject bribery in all its forms	.275	**.509**	−.077	.354
A1 Hold paramount the safety, health and welfare of the public	.145	.076	**.788**	.111
A19 Protect the environment	.266	.131	**.747**	.203
A16 Be humanism	.172	.340	**.704**	−.002
A3 Prevent the distortion of professional judgment	.095	.250	−.145	**.664**
A22 Abide by the laws and industry rules	.228	−.014	.397	**.656**
A4 Be safe, reliable and responsible for others	.260	−.055	.386	**.640**
A13 Tell product/technology's negative impact/defects in an objective and truthful manner	.092	.227	.111	**.621**
Eigenvalue	3.181	2.493	2.364	**2.105**
Variance %	18.713	14.666	13.904	**12.380**
Total variance %	18.713	33.378	47.282	**59.662**

8 items out of 25 original guidelines were deleted (A2 Be supreme to the employers; A5 Be prudent and diligent; A10 Respect everyone; A11 Cooperate with each other; A12 Be responsible for your own behaviors; A14 Acting with integrity; A15 Accept suggestions with modesty; A23 Care for nature) after repeated exploratory factor analysis, considering the results of document analysis, relevant coefficients of various evaluation indicators, and various data analysis results of the above-mentioned importance order, mean value and standard deviation. The rest 17 items will be output as the factor analysis results of code of ethics which we initially select. See Table 3 for more details.

From Table 4, it shows that the four common factors can explain 59.662% of the variation amount in the code of ethics.

According to the above-mentioned factor analysis results, the structure of code of ethics for engineers includes four factors as follows:

Factor 1 includes 6 items. It reflects a professional requirement and standard for engineers to treat their jobs, and thus named as "professional attitudes".

Factor 2 includes 4 items. It reflects the behavior quality of engineers, which reflects more about the quality and behavior shown in their jobs, and thus named as "professional characteristics".

Factor 3 includes 3 items. It reflects engineers' pursuit for a basic principle and a higher beliefs in their engineering practice, and thus named as "professional beliefs".

Factor 4 includes 4 items. It reflects the behavior of engineers to respect the facts and be pragmatic and compliant, and thus named as "professional responsibility".

2.2.2 Difference in Evaluation Between University Faculty and Engineers

In order to learn about university faculty and engineers group evaluation on the importance of codes of ethics, we did T-test on the four dimensions and all the items.

Table 4 presents the T-test results to compare the means of university faculty group and engineers group on the four ethic dimensions. As is shown in the table, there was a significant difference on the "professional beliefs" dimension between the two groups. Specifically, the mean for the university faculty group was 13.64 and that for the engineer group was 12.78. It showed that the university faculty group was higher than the engineer group in the evaluation of importance in this ethical guideline and job responsibilities' expectations.

Table 4. Difference in evaluation of the importance of four ethic dimensions of engineers between different groups

Ethic dimension	Group	N	Mean	Std. Dev.	T-value	Sig.
Work ethos	University Faculty	105	24.69	3.17	−1.531	.127
	Engineers	100	25.40	3.41		
Conduct features	University Faculty	105	17.92	2.12	.938	.349
	Engineers	100	17.64	2.21		
Professional beliefs	University Faculty	105	13.64	1.36	3.746	.000***
	Engineers	100	12.78	1.87		
Responsibility quality	University Faculty	105	17.98	1.83	1.013	.312
	Engineers	100	17.72	1.85		

In order to learn further about the evaluation difference of this two groups, the research did T-test on every items in this dimension. The results showed that except the significant difference in the three items (A1, A16, A19) of "professional beliefs" dimension, there was also a difference on the items A2, A7, A11, A15 and A20 ($p < 0.05$). Among them, on the items A1, A7, A16 and A19, the mean of university faculty group was higher than that of engineers, which reinforces the previous finding that university faculty pay more attention to cultivating future engineers on higher level of value and world view.

However, on the items A2, A11, A15 and A20, the means of engineers were higher than that of faculty, suggesting that the engineers were more realistic and emphasize more on ethics relevant to work practices. As for the item of A2 "employer come first", in particular, the average score of the engineer group was statistically significant higher than that of the university faculty group. It implied that engineers need to consider the employer's requirements and act in accordance with their demand on many occasions in the engineering activities.

2.3 Variation Analysis on Importance Ranking Results

In the research, we summed up the samples of importance ranking in the second part of the questionnaire. There were totally 56 samples of university faculty and 100 samples of engineer in effective. We endowed the indicator on the first important A1 with 5 points, the indicator on the second important A2 with 4 points, and on the analogy of this. The indicator on the fifth important A5 was endowed with1 point. The total score for each selected importance indicator was calculated, then divided by effective samples amount to get the average score of items.

By making statistical analysis on the university faculty groups and the importance ranking results of code of ethics, the paper found that the top 5 ethic guidelines are A1, A4, A6, A7 and A12 (both rank the fourth), and A13.

As to the importance ranking of engineering ethics codes for the engineer group, the top 5 were A1, A11, A6, A4 and A2. Research found that, in the top five the university faculty group had the similar evaluation to the engineer group as to the three guidelines of A1, A4 and A6. In general, as to the importance evaluation of code of ethics, the university faculty pay more attention to the universal code of ethics and moral quality such as justice, equity and integrity. The engineer group, however, pay more attention to practicality and the cooperation in engineering practice activities besides the evaluation of universal value. This was an indispensable element for the completion of any project implementation. Meanwhile, the engineer group pay more attention to practicality and the requirements of employers. It was consistent with the analysis results of the two different groups mentioned above.

3 Conclusions and Implications

3.1 Conclusion

Through the review on publication and engineering associations' regulations, this study found that the formulation of code of ethics and standards by engineering associations in China were paid less attention. Discussions on engineering guideline codes were usually in academic studies. For one thing, it showed that researches on Chinese engineering ethics were being internally held and secluded in associations, corporations and specific authorities, but were not publicly published to the society. For the other thing, researches on code of ethics for engineers in Mainland China are now still limited to just a small group of scholars in the academic community. They were still under development and received little attention from the government, educational institutions and social organizations. Furthermore, no uniform and specialized code of ethics for engineers have been formulated in China.

Through the exploratory factor analysis, the study found that the content and structure of code of ethics consisted of four dimensions: "professional attitudes", "professional characteristics", "professional beliefs" and "professional responsibility". Furthermore, using independent-sample T-test of rated importance level of code of ethics between engineers in the industry and university faculty who taught ethics training courses, the paper reveals a statistically significant difference in selecting code of ethics between the two groups. The average score of the university faculty group was statistically significant higher than that of the engineer group on items such as "to put the public security, health and welfare in the first place", "impartial" and "humanitarianism", and etc., and the engineers rated significantly higher on items closely related to the engineering practice activities such as employer-oriented, coordination and collaboration, and etc.

3.2 Implications

1. The code of ethics for engineers have some international and industrial universality. The paper found that there are some similarities between researches on engineering ethics both at home and abroad. In China, the USA and other countries, people basically agree on the guidelines such as objective, truthful, honest, neutral, trustworthy, fair, white-handed (not offering or accepting bribes), etc. In this research, engineers from different industries, and university faculty who taught ethic courses in general presented a similarity in the evaluation of most contents in the code of ethics for engineers.
2. The construction of the codes of ethics for engineers shall be complete in ideological and behavioral norms. As is shown in our questionnaire and the quantitative analysis results, the structure of the code of ethics for engineers consists of four dimensions, namely "professional attitudes", "professional characteristics", "professional beliefs" and "professional responsibility". Therefore, the design of relatively ideal engineering ethic guidelines shall have functions such as theory direction, behavior restriction and quality creation. The ethical guideline structure

system with complete structures and functions can help better educate and manage engineers, improve engineering education and cultivate excellent engineers.

3. There were some differences between the engineering ethical education and practice. In the engineering ethical education, our goal is to cultivate engineers with high ethical qualities. According to the variation analysis on the rated importance level, there were some different preferences between the university ethical educators and engineers in selecting the items of code of ethics. From this aspect, on one hand, communication and discussion between the two groups must be strengthened and on the other hand, universities should adjust their teaching and education aims to close the gaps between the academia and the industry, so as to ensure that engineering ethical education, while presenting to students a moral level that is higher than the actual requirements, still stick to the real demands of the industry.

In recent years, the research of engineering ethics is receiving more and more attention. This research is just an exploratory study. Due to objective conditions, this paper investigated two groups mainly—university teachers and engineers. In order to know more about the issue, the research range will be expanded in the further study.

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A Study on the Educational Effectiveness of the Industry Professional Practice (IPP) Program

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Abstract. The objective of this chapter is to examine the effects of Industry Professional Practice (IPP), a long-term on-site training program. To achieve this, two groups of students answered multiple questions that pertained to four categories: “major”, “career”, “personal relationships”, and “problem-solving”. The first group consisted of 36 students currently enrolled at a university in Cheonan, Korea, and who participated in the IPP program (and have since returned to university). The other group consisted of 60 regular students at the same university who had never participated in the IPP program.

First, in the “major” category, IPP students displayed a higher score on the first of the six questions; demonstrating a statistically significant difference compared with non-IPP students. Second, in the “career” category, compared with non-IPP students, IPP students displayed a higher average score for all 4 questions – with a particularly high score and notably significant difference on the third question. Third, in the “personal relationships” category, IPP students displayed higher scores and a statistically significant difference on the second question (compared with non-IPP students). Fourth, concerning the “problem-solving” category, IPP students scored lower on the second question compared to the scores of non-IPP students, but this was not considered statistically significant. The results of the regression analysis showed that participation in the IPP program had a positive effect on the entire category of “career”, and on the aforementioned questions from both the “major” and “personal relationships” categories. Based on the results from this study, it is likely that participating in the IPP training program will enhance the education of Korean engineering students in the future.

1 Introduction

1.1 Need for Study

Cooperative (co-op) education programs, designed to promote education and work experience by applying knowledge acquired from school into practice at industrial

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sites, are in operation at 217 universities around the world. Each of these programs are members of WACE[1]. In Korea, the term "on-site training" (in its application for engineering students) was first used in the Industrial Education Promotion Act of 1973, and the on-site training duration was less than 4 weeks. After that, in 1998, long-term cooperative education first began under the title of "sandwich educational process", with the duration of the work experience expanding from four weeks to one semester. However, to solve the low efficiency results of short-term on-site training programs, and to increase students' practical skills, Korea University of Technology and Education (Koreatech) created an overseas co-op program (in compliance with Korean university education requirements) and launched its "Industry Professional Practice" (IPP) program, a *long-term* on-site training program. Students in their 3rd or 4th year of study were granted access to the IPP program in order to gain work experience for four to six months at a site related to their specific major.

According to a 2015 study by the National Academy of Engineering of Korea in which problems of engineering education (involving a total of 700 professors, students, and industrial workers) were investigated, the category of "insufficient cultivation of practical engineering skills" (21.0%) accounted for the highest proportion. Moreover, more than half of the responders indicated the category "cultivation of practical skills" (58.8%) as the category that required the most improvement.[2] As demonstrated by the results above, it is suggested, by both academia and the industry, that Korean engineering education should require a more devoted effort into cultivating practical skills needed at industrial sites. Since various cooperative skills are also required on-site (as well as the ability to practically apply the theoretical knowledge acquired from a major), it is necessary to cultivate such skills at industrial sites outside of school. In this regard, the IPP program contributes to solving this problem of Korean university education not adequately preparing students for working in their respective fields. Additionally, it aims to satisfy a company's demand for a competent workforce with practical skills. Therefore, verifying the IPP program's effectiveness in reaching the goal of cultivating students' practical skills related to their major is essential for the continuation of on-site training programs and the fostering of an outstanding workforce.

1.2 Restrictions of Study

There were certain restrictions involved with this study. First, not *all* four-year-university students performing long-term on-site training in Korea were included in the research, and thus, there were restrictions in standardizing the results. Second, elements from universities and corporations that may have influenced the effectiveness that the long-term on-site training had on students were not included in this study. For example, mentors who were in charge of the student evaluations at the

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[1] The World Council and Assembly on Cooperative Education. WACE was founded in 1983 to foster cooperative education and other work integrated learning programs worldwide. http://www.waceinc.org/history.html.

[2] Korea Engineering Academy's Next Generation Engineering Education Committee, Next Generation Engineering Education Innovative Plan Study, November 27, 2015. 218.

corporations, or the way the program is specifically run by a certain university, may have also had an effect.

2 Long-Term Cooperative Education Program: IPP

2.1 Semester-Based Quarterly System

It is difficult to compose separately a practical semester for students participating in a long-term on-site training program, other than as part of the 8 semesters of the usual four-year bachelor's degree in the Korean academic system. Considering the disadvantages of late entry into the employment market, and the financial burden of when the term of enrollment increases, the IPP program operates a bachelor's degree system that enables participating students to earn enough credits to graduate within 8 semesters. To achieve this, the existing academic system, composed of two semesters per year (i.e. one spring and fall semester), was changed to a quarterly system, with 8 quarters in the students' third and fourth year.

Currently, there are two tracks (A and B) available for students in the IPP program. For instance, Track A courses relating to one's major are held intensively in the summer semester (for seven and a half weeks), and the practical work experience lasts from the fall semester to the winter semester. Track A consists of IPP1, which starts in the second semester of the third year, and IPP2, which starts in the second semester of the fourth year. The duration of IPP1 is four to six months, depending on the demands of the companies. The duration of IPP2 is just four months. Students can participate in both IPP1 and IPP2, which lasts up to a maximum of ten months, or they can choose to participate in only one of the programs. The semester-based "quarterly system", as previously mentioned, is shown below in Table 1:

Table 1. Co-op education plan

Yr	Track	Spring	Summer	Fall	Winter
First year	Track A	Class (20)	–	Class (20)	–
	Track B	Class (20)	–	Class (20)	–
Second year	Track A	Class (20)	–	Class (20)	–
	Track B	Class (20)	–	Class (20)	Class (9)
Third year	Track A	Class (20)	Class (9)	IPP1(9)	
	Track B	IPP1 (9)		Class (20)	Class (6)
Fourth year	Track A	Class (20)	Class (6)	IPP2 (6)	–
	Track B	IPP2 (6)	–	Class (20)	–

(*The number in parentheses refer to the required credits)

2.2 IPP Credit

Students participating in the IPP program receive a total of 15 credits over 10 months (1.5 credits for each month of on-site training), which is the maximum period in which a student can participate. This accounts for 10% of the total number of credits required for graduation, and with respect to major-related credits, 3 credits are acknowledged in IPP1, and 2 to 4 credits in IPP2. For example, if a student participates in track A, 120 of the required 150 credits are obtained in the 6 regular quarters, and another 15 credits are obtained in the two IPP quarters. The remaining 15 credits can be obtained through e-learning during the IPP quarters and summer school. Therefore, the IPP participants can also graduate in four years, even though they also did 10 months of on-site training. For the major-related theory classes, which are missed during the regular semesters due to participation in IPP, substitute classes are held during the semester breaks exclusively for students participating in IPP. Therefore, a gap between IPP students and non-IPP students (in terms of their understanding of their major, in addition to keeping up with the semester's classes) is avoided.

The assessment of a student's performance during the on-site training is either "pass" or "fail". If at least 70 of the 100 points are achieved (based on the student's monthly reports, final report, and work behavior), this is considered a passing score. 30% of the assessment is made by the student's supervising professor during the IPP quarter; another 30% by the student's mentor at the corporation; 20% by the HRD[3] professor; and the remaining 20% by the student's professor of their respective major.

2.3 On-Site Training and IPP

The term "on-site training" is frequently understood as having a similar meaning to "internship" in Korea.[4] However, the concept of on-site training and internship have slight differences, such as the range of participation, operating body, relation to the major, and relation to employment. On-site training is also called "work-based learning", which has thus far been actively implemented at applied science university departments, such as child education, nursing, social welfare, etc. The on-site training required by these departments is a part of the curriculum, which must be completed in order to obtain a license before graduation. A student typically undergoes on-site training immediately prior to obtaining their degree.

With respect to engineering departments, the demand for engineering students with practical skills is also constantly increasing. This has resulted in the introduction of on-site training courses (each ranging from 4–12 weeks in length) in 84.6% of the four-year engineering courses in South Korea, as of 2015. However, according to the results of the study by Choi (2010), although most of the students generally displayed a positive response toward internships conducted between 4–6 weeks, the lack of specific work related to their major and non-systematic work instructions were both indicated as

[3] HRD stands for Human Resource Development. Cooperative education of KOREATECH is related to the educational goals of KOREATECH's HRD in order to foster the basic ability to be to design and explore one's own career. So HRD professors also evaluate cooperative education results. http://cms3.koreatech.ac.kr/general/index.do?sso=ok.

[4] U. T. Hwang (2015), A Study on the Effect of Employing Labor Force through the Industry Professional Practice System, Unpublished Doctorate Dissertation, University of Seoul Graduate School Department of Management, Seoul, 33.

problems, and the need for work-related mentors was expressed as well.[5] Existing internships and on-site training are considered to be "on-the-job training" (OJT) in order to adapt to the site and obtain knowledge of the work. However, the students found it difficult to carry out any actual meaningful work. Because of this, students were given simple tasks, and thus, were not provided with the opportunity of directly participating in work related to their major, regardless of their degree of participation in on-site training. Therefore, it is difficult to expect 4–6-week on-site training to be any more advantageous than simply a slightly prolonged visitation to an industrial site. In contrast, the features that distinguish a long-term program from the existing on-site training programs in Korea are outlined below.

First, according to CAFCE (Canadian Association for Co-operative Education), an on-site training program must provide relevant work for a student based on the academic curriculum of the student's respective major, which is developed and approved by the on-site training institution. Second, both the on-site training institution and the company must then systematically manage and evaluate the student's work performance. Third, the student must receive suitable compensation for their work. Fourth, the student's work performance must then be inspected by the on-site training institution.[6] Because of these features, long-term on-site training is understood to be an educational program that cultivates students' capabilities involving their major, social skills, career prospects, and problem-solving abilities. The IPP program was designed to address the shortcomings of the aforementioned long-term on-site training (as opposed to short-term on-site training).

3 Prior Studies

Numerous studies exist involving internships (usually conducted during the summer break), using the model from practical academies where, during a semester-length period (4–6 weeks), students alternate between practice and classes. With respect to on-site training for engineering students, there are many studies related to the means of operation and improvement of cooperative education, but there are not many related to the effectiveness of the practical experience of students who have participated in these programs. Kim et al. (2000) researched these effects and improvements concerning cooperative education with third-year students from engineering departments who participated in on-site training for one semester.[7] It was reported that 78.9% of the students who participated in this study gave a positive response regarding the need for cultivating practical skills and cooperative education. Kim (2000) researched the value recognition from engineering students who participated in cooperative education, and reported that although the students agreed that cooperative education may enhance their

[5] A. K. Choi (2010), "Current Status and Task of Corporate Internships by University Students," Commercial Education Study, Vol. 24, No. 2, 23–47.

[6] Y. Tanaka (2015), The Economics of Cooperative Education, Routledge, Oxon, 14.

[7] S. G. Kim, D. H. Cho, & S. H. Lee (2000), "A Study on the Efficient Operation and Improvement of the Semester Sandwich System," Thesis Collection: Natural Science, Human Science, and Social Science, 17, 457–480.

practical or occupational skills, cooperative education is passive in educational values; i.e., the obtainment of knowledge in the field of their respective major, development of leadership skills, and the establishment of life values, all of which are features obtained from long-term cooperative education.[8]

4 Study Procedure

This study conducted a survey among fourth-year male and female students currently enrolled at a university, dividing them into two categories: those who have never participated in IPP, and those who have. The student sample was randomly selected. The survey took place from December 2015 to January 2016, and there was a total of 96 respondents (comprised of 36 IPP participants (37.5%), and 60 non-IPP participants (62.5%)).

4.1 Analysis

After the survey was completed, technical statistics and an element analysis of the SPSS program, t-test, and regression analyses were used to statistically process the results.

4.2 Properties of the Participants

A total of 96 respondents participated in the survey (both IPP- and non-IPP students were randomly selected among fourth-year students). With respect to the gender of the

Table 2. Properties of participants

		Total	IPP students	Non-IPP students
		Amount (%)	Amount (%)	Amount (%)
Gender	Male	67 (69.8%)	21 (58.3%)	46 (76.7%)
	Female	29 (30.2%)	15 (41.7%)	14 (23.3%)
Department	Mechanical Engineering	9 (9.4%)	3 (8.3%)	6 (10.0%)
	Mechatronics Engineering	17 (17.7%)	6 (16.7%)	11 (18.3%)
	Electrical, Electronics and Communication Engineering	13 (13.5%)	4 (11.1%)	9 (15.0%)
	Computer Engineering	4 (4.2%)	2 (5.6%)	2 (3.3%)
	Design Engineering	7 (7.3%)	1 (2.8%)	6 (10.0%)
	Architecture Engineering	5 (5.2%)	4 (11.1%)	1 (1.7%)
	Energy And New Material Engineering	11 (11.5%)	4 (11.1%)	7 (11.7%)
	Industrial Management	30 (31.3%)	12 (33.3%)	18 (30.0%)
Total		96 (100.0%)	36 (100.0%)	60 (100.0%)

[8] S. G. Kim (2000), "A Study on the Recognition of Value of the University Semester Sandwich Education System," Higher Education Study, Vol. 11, No. 1, 1–23.

students, among the IPP students, 21 were male (58.3%) and 15 were female (41.7%). Regarding the non-IPP students, 46 were male (76.7%) and 14 were female (23.3%). With respect to the percentages of the departments, more than 30% of both the IPP students and non-IPP students were in the industrial management department; followed by 6 IPP students (16.7%) and 11 non-IPP students (18.3%) from the mechatronics engineering department. The department with the lowest number of participants included 1 IPP student (2.8%) from the design engineering department, and 1 non-IPP student (1.7%) from the architectural engineering department. However, students from all of the 8 departments were included in both categories of respondents (Table 2).

5 Results

5.1 Verification of Measurement Tools

This study conducted a factor analysis to verify the validity of the four categories (major, career, personal relationships, and problem-solving) in the survey. In all four categories, the KMO (Kaiser-Meyer-Olkin Measure of Sampling Adequacy) value was higher than 0.6, and the significant probability using Bartlett's test was lower than 0.05. Thus, the selection of variables for the factor analysis was suitable. The variance explanation power was less than 50% in some cases, but the difference was minor. Therefore, the overall validity was maintained (Table 3).

Table 3. Validity test of survey questions

	KMO	Bartlett's test	Eigen value	% of variance
Major	.714	.000	2.774	46.241
Career	.683	.000	1.982	49.543
Personal relationships	.804	.000	3.081	51.358
Problem-solving	.791	.000	2.968	49.467

In the credibility analysis of the survey questions, the Cronbach α coefficient was above 0.6 in all of the categories (major, career, personal relationships, and problem solving), as displayed in the credibility analysis results Table 4. Generally, credibility is evaluated based on whether the result is above or below 0.6, and thus, the categories of the factors found in this study are deemed to be credible.

Table 4. Credibility analysis of the survey questions

Variables	Number of questions	Cronbach's α
Major	6	.741
Career	4	.640
Personal relationships	6	.786
Problem-solving	6	.795

The following is the list of questions asked of the participants:

Major

Q1. I can understand and analyze the theoretical knowledge and data involved with my major
Q2. I can apply the knowledge from my major to the work environment
Q3. I can plan and execute an experiment/program/project
Q4. I am aware of my practical skills
Q5. My motivation for my major's studies is high
Q6. I select my elective classes while considering my career goals

Career

Q1. I have a plan for what I will do after graduation
Q2. I know what to do in order to achieve my career goals
Q3. I researched an institution and/or corporation that I was interested in before deciding on my career
Q4. I am aware of my shortcomings regarding my career and profession choices

Personal Relationships

Q1. I have the leadership skills necessary to persuade my team members
Q2. I can exchange opinions with others to find a compromise
Q3. I can cooperate with people from different backgrounds through forming cooperative relationships
Q4. I have knowledge and an understanding of other cultures, and am aware of the effects of globalization
Q5. I understand my organization, contribute to the community spirit, and act responsibly
Q6. I can manage and control my personal conflicts

Problem Solving

Q1. I have tried to solve a problem with a new solution method of my own
Q2. I tend to further develop my initial ideas regarding problems into better ideas
Q3. I analyze the cause or meaning of a problem on several levels
Q4. I can approach problems in a rational and critical way by gathering knowledge
Q5. I can propose and evaluate solutions to problems
Q6. I can develop and carry out a plan to solve problems

5.2 Technical Statistics Analysis

Looking at the score of each question in the four categories between the IPP students and non-IPP students, the greatest difference was seen in the analysis of Q1 ("I can understand and analyze my major's theoretical knowledge and data"). A score of 4.03 was displayed with IPP students and 3.58 with non-IPP students, with a difference of 0.45 between the IPP students and non-IPP students' average. This was followed by a score of 3.58 with IPP students and 3.37 with non-IPP students with Q5 ("My motivation for my major's studies is high"), with a difference of 0.21 in the average scores.

With respect to the career category, the difference between the average scores between the two target groups was the greatest with Q3 ("I researched an institution and/or corporation that I am interested in before deciding on my career"). Specifically, 4.22 was recorded among IPP participants and 3.68 among non-IPP participants, displaying a difference of 0.54 between the two groups.

With respect to personal relationships, the average for IPP students and non-IPP students was 4.11 and 3.85, respectively, for Q2 ("I can exchange opinions with others and find a better compromise"), and the difference between the two target groups was 0.26.

Regarding problem-solving capacity, the average score of IPP students and non-IPP students was 3.81 and 3.47, respectively, for Q2 ("I tend to further develop my initial

Table 5. Relationship between participation in IPP and the four categories

		Total		IPP students		Non-IPP students		t-test	
Major		Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	T	p
	Q1	3.75	0.754	4.03	0.560	3.58	0.809	3.174**	0.002
	Q2	3.44	0.765	3.56	0.695	3.37	0.802	1.173	0.244
	Q3	3.55	0.819	3.69	0.822	3.47	0.812	1.324	0.189
	Q4	3.57	0.764	3.61	0.766	3.55	0.769	0.378	0.707
	Q5	3.39	0.910	3.58	0.841	3.27	0.936	1.665	0.099
	Q6	3.52	1.036	3.56	0.969	3.50	1.081	0.253	0.801
	Average	3.54	0.559	3.67	0.497	3.46	0.583	1.852	0.067
Career	Q1	3.65	0.821	3.75	0.732	3.58	0.869	0.963	0.338
	Q2	3.61	0.887	3.83	0.845	3.48	0.892	1.897	0.061
	Q3	3.89	0.983	4.22	0.797	3.68	1.033	2.685**	0.009
	Q4	3.99	0.761	4.00	0.756	3.98	0.770	0.103	0.918
	Average	3.78	0.601	3.95	0.547	3.68	0.614	2.155*	0.034
Personal relationships	Q1	3.45	0.832	3.47	0.654	3.43	0.927	0.240	0.811
	Q2	3.95	0.587	4.11	0.319	3.85	0.685	2.532*	0.013
	Q3	3.96	0.631	4.08	0.439	3.88	0.715	1.697	0.093
	Q4	3.46	0.905	3.33	0.894	3.53	0.911	1.049	0.297
	Q5	3.94	0.723	3.94	0.583	3.93	0.800	0.073	0.942
	Q6	3.67	0.749	3.75	0.604	3.62	0.825	0.910	0.365
	Average	3.74	0.518	3.78	0.356	3.71	0.596	0.762	0.448
Problem-solving	Q1	3.74	0.771	3.72	0.741	3.75	0.795	0.170	0.865
	Q2	3.59	0.828	3.81	0.856	3.47	0.791	1.970	0.052
	Q3	3.81	0.772	3.83	0.737	3.80	0.798	0.204	0.839
	Q4	3.77	0.801	3.92	0.770	3.68	0.813	1.388	0.168
	Q5	3.73	0.852	3.86	0.762	3.65	0.899	1.178	0.242
	Q6	3.79	0.739	3.94	0.791	3.70	0.696	1.582	0.117
	Average	3.74	0.558	3.85	0.531	3.67	0.569	1.472	0.144

*Between group difference ($p < .05$) **Between group difference ($p < .01$)

ideas regarding problems into better ideas"), with a difference of 0.34 between the two target groups. Next, the question that displayed a noticeably high difference in the average between the two target groups (with respect to problem solving capacity), was Q6 ("I can develop and carry out a plan to solve problems"), which displayed an average of 3.95 for IPP students and 3.70 for non-IPP students, resulting in a difference of 0.24.

A t-test was conducted to determine whether there was a difference between the averages in the two target groups with respect to the survey questions. The results of analysis are displayed in Table 5.

A statistical significance was displayed in the difference between the averages of the two target groups in Q1 (in the category of major), Q3 (in the category of career), and Q2 (in the category of personal relationships), in addition to the total average in the category of career.

5.3 The Results of the Regression Analysis

Based on the results of the t-test displayed in Table 5, a regression analysis was conducted for the 4 categories, which displayed statistically significant differences based on participation in the IPP program. The research hypotheses for this are set listed below:

Hypothesis 1: "Participation in IPP" will have a positive effect on the "career category".
Hypothesis 2: "Participation in IPP" will have a positive effect on "Q1: Understanding and Analysis of the Theory and Data of a Major".
Hypothesis 3: "Participation in IPP" will have a positive effect on "Q3: Finding Information regarding an Institution and Corporation of Interest".
Hypothesis 4: "Participation in IPP" will have a positive effect on "Q2: Exchange of Opinions and Deduction of a better Compromises".

A regression analysis was conducted with "participation in IPP" as the independent variable and "career category" as the dependent variable. The significant probability of $p = 0.034$ was smaller than 0.05, and, thus, was deemed a suitable regression formula. Furthermore, the significant probability of the dependent variable, "category of career", was 0.034, which is smaller than 0.05, and the t value was positive. Therefore, Hypothesis 1 was confirmed. However, R2, which displays the explanation power of the independent variable with respect to the dependent variable, was very low (at 0.047) (Table 6).

Moreover, conducting a regression analysis by having "participation in IPP" as the independent variable and "Q1 of Major" as the dependent variable, the significant probability, 0.005, was smaller than 0.05, and was therefore deemed a suitable regression formula. Furthermore, the significant probability of the dependent variable, "Q1 of Major", was 0.005, which is smaller than 0.05, and the t value was positive. Thus, conclusively, Hypothesis 2 was confirmed. However, R2, which displays the explanation power of the independent variable with respect to the dependent variable, was very low (at 0.082).

Table 6. Regression analysis of the categories that display a statistically significant difference

Independent variable	Dependent variable	B	Std. error	β	t value	Sig.	Statistical amount
IPP-participants	Constant	3.683	.076	–	48.365	.000	R = 0.217 R^2 = 0.047 Adjusted R^2 = 0.037 F = 4.646 p = 0.034
	Category of career	.268	.124	.217	2.155	.034	
	Constant	3.583	.094	–	38.228	.000	R = 0.287 R^2 = 0.082 Adjusted R^2 = 0.073 F = 8.430 p = 0.005
	Major Q1. I can understand and analyze my major's theoretical knowledge and data	.444	.153	.287	2.904	.005	
	Constant	3.683	.123	–	29.967	.000	R = 0.267 R^2 = 0.071 Adjusted R^2 = 0.061 F = 7.208 p = 0.009
	Career Q3. I researched an institution and/or corporation that I am interested in before deciding on my career	.539	.201	.267	2.685	.009	
	Constant	3.850	.074	–	51.759	.000	R = 0.216 R^2 = 0.047 Adjusted R^2 = 0.037 F = 4.621 p = 0.034
	Personal relationships Q2. I can exchange opinions with others and find a better compromise	.261	.121	.216	2.150	.034	

From the regression analysis applied to having "participation in IPP" as the independent variable and "Q3 of Career" as the dependent variable, the significant probability, 0.009, was smaller than 0.05, and thus deemed a suitable regression formula. Furthermore, the significant probability of the dependent variable, "Q3 of Career", was 0.009, which is smaller than 0.05, and the t value was a positive value. Therefore, Hypothesis 3 was confirmed. However, R2, which displays the explanation power of the independent variable with respect to the dependent variable, was very low (at 0.071).

Upon conducting a regression analysis with "participation in IPP" as the independent variable and "Q2 of Personal Relationship" as the dependent variable, the significant probability, 0.034, was smaller than 0.05, and thus, was deemed a suitable regression formula. Furthermore, the significant probability of the dependent variable, "Q2 of Personal Relationship", was 0.034, which is smaller than 0.05, and the t value was a positive value. Conclusively, Hypothesis 4 was confirmed. However, R2, which displays the explanation power of the independent variable with respect to the dependent variable, was very low (at 0.047).

6 Discussion and Conclusion

This study's objective was an examination of the effects of long-term on-site training for participants concerning the categories of major, career, personal relationship, and problem-solving. The discussion and implications related to the results of this study are as follows:

First, it was noted that the IPP experience has a significant effect on the "career" category. Through the experience of being in a real, working environment, IPP students had the opportunity for personal growth. IPP students realistically understood the skills required for their desired job or career while performing specific tasks at an industrial site. However, they were also simultaneously able to recognize their own personal deficits in this regard. Through these experiences during their on-site training, IPP students displayed an improved competency in preparing for their own career, including researching information concerning their career of interest (rather than just vaguely preparing).

Second, some professors had apprehensions as to whether long-term, on-site training may decrease the students' competency regarding their major due to missing certain classes required for their majors during the on-site training period. However, IPP students evaluated themselves more positively than non-IPP students in terms of understanding and analyzing theoretical knowledge and data. This is due to their increased self-confidence stemming from their major-related experiences on-site, including design, process management, business support, quality management, laboratory experiments, research and development, etc. Accordingly, seeing the real life applications of the theoretical information related to their major evoked a personal internalization that went beyond merely "understanding" basic theories. Therefore, companies can expect a shortened "adjustment phase" and less additional training for new employees who have previously undergone long-term on-site training. All in all, it can be said that for effective work experience involving engineering education in the future, long-term on-site training is needed.

Third, the IPP program was seen as having a positive effect on IPP students with respect to the mutual exchange of opinions and the ability to reach a compromise (in the "personal relationships" category). In our global society of the 21st century, which demands cooperative skills with neighboring domains, communication and cooperation skills are considered significant occupational capabilities, and are just as important as capabilities required only for one's major. In this regard, long-term on-site training has a positive effect on participants' acquisition of non-technical "soft skills", which are inadequately taught in today's university curriculums (compared to what is actually demanded in the occupational world).

Fourth, there was no statistical significance in any of the questions in the "problem-solving" category between IPP students and non-IPP students. In an era where the speed of technology is rapidly increasing, and where new levels of technology are generated by combining technologies from different areas, engineers need creative problem-solving skills rather than merely having the answers to a given set of problems. Although industry professional practice is an area limited to its participants, it must allow for the maintenance of interest in practical work in order to inspire creativity and innovation among its participants. To achieve this, the importance of mentors and professors, who stimulate and lead the expansion of thought by searching for solutions, must be emphasized.[9]

The significance of this study is as set forth below:

First, it was determined that the IPP program has a positive effect on the participants in terms of capabilities regarding their majors. Although Kim (2000) reported that the students were passive with regard to the recognition of the educational value of long-term on-site training (i.e. the value of obtaining knowledge in their field of major), IPP actually has a positive effect on understanding and analyzing theoretical knowledge and data, in addition to increasing participants' self-confidence through major-related practice.

Second, it was observed that IPP acts as a positive influence on the behavior of those preparing for a career, as well as for determining a career path. Students who have experienced on-site training displayed more activity in preparing for their career compared with non-participants due to their increased career understanding. Herein, it was deemed that industry professional practice is not only effective in allowing the students to gain credits (and an income) during their period of practice, but also in the preparation and formation of an attitude that will determine their future career path(s).

Third, it was found that IPP has a positive influence on forming technical and non-technical skills. The experience of practical performance at a site for 6–10 months with IPP positively influenced the students' cooperation and attitudes. Accordingly, IPP is expected to perform its role as an effective program to nurture the future workforce's major and non-major practical skills which are required on-site and ensure adaptability.

The restrictions of this study, and the proposal for a succeeding study, are as follows:

First, because this study does not take into account *all* long-term on-site training participants at four-year-universities in Korea, results may differ with similar research conducted by other universities. Thus, it is believed that further studies need to examine possible differences found at other universities. Second, although the direct effects of the students' corporative mentor and university IPP professor (both responsible for managing the participants at the company institute/corporation and university, respectively) were not included in the analysis, it is believed that examining the effect of these variables will prove to be significant.

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Introducing Responsible Resource Management to the Engineering Education

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Abstract. The article encompasses the results of Tomsk Polytechnic University research on principles of Responsible Resource Management; underlines the approach implemented at TPU for enhancing engineering education in line with these principles and fostering students' sustainability competences and mindset. Best practices of creating specific educational environments at universities for fostering students' mindset are addressed. The concept of Responsible Education is proposed.

Keywords: Responsible resource management · Responsible Education · Engineering education · Sustainable Development · Specific learning environment

1 Introduction

One of the core and fundamental principles of Sustainable Development is responsible consuming of natural resources in order to maintain and better to increase them for future generations. According to the United Nations sustainability was defined as "development…meeting the needs of the present without compromising the ability of future generations to meet their own needs" and further underlined the concern "about the accelerating deterioration of the human environment and natural resources, and the consequences of that deterioration for economic and social development…" (United Nations General Assembly Report of the World Commission on Environment and Development, 1987) [1].

The implementation of this principle is not possible without the formation of a special world outlook of each member of the society - the mindset of responsibility for the expenditure of resources and conditions regulating the use of resources. Essentially, it involves social responsibility of each member of our society and communities at large (companies, enterprises, public organizations and others.) This personal and corporate responsibility includes social consequences of all their activities and all kinds of their decisions concerning not only consuming exhaustible resources and resource saving, but also the measures taken to create conditions necessary for this.

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It is not a coincidence that in the modern world such trends as Responsible Research and Innovations, Responsible Industry, Technology Assessment, and similar, exist and develop.

We can assume that an integrating condition for the realization of any of these trends is not limited to the formation of particular competences of each person (specialist), participating in the decision-making process. It is dramatically important to manage development of sustainability mindset and social responsibility competences [2].

According to the National Doctrine of engineering education proposed by the Association for Engineering Education of Russia, when speaking of the development of a society, a country or a civilization the following hypotheses have to be taken into account:

1. The world development is based on competition;
2. In a struggle (competition) of two cultures and civilizations the culture and civilization of a lower level dies or falls in stagnation;
3. The cultural and civil level of a society (nation, country, people) is defined by the level of its education;
4. Education in a society depends, to a great extent, on the education level of society in general and that of every person, in particular;
5. The level of knowledge and education in a society, especially in the sphere of technology and engineering, defines the level of its general and engineering culture, “technological sensibility”, “innovative resistance” and, hence, defines the vector of society development, forms the potential necessary for winning in competition on the global market;
6. A large part of educated population in a society is fundamental to form cultural, scientific, and engineering elite, whose activities could lead to breakthroughs in the mentioned spheres and guarantee the victory in competition on world markets, in case appropriate working and living conditions are provided;
7. Society with a higher level of knowledge and education is considered to be less conflicting, characterized by a higher level of general, economic, social, spiritual, engineering, ecological and physical cultures, and, therefore, provides decent conditions for life and development of every person [3].

These hypotheses underline the importance and the crucial role of education for the society development, thus indicating that in order to implement the stated above conditions for Sustainable Development it is necessary to assure active and decisive contribution of the education system at all stages. New models for sustainable education must be aimed at changing the mindsets of future generations beginning at an early age then fostered through formal education at undergraduate, graduate and professional levels.

2 Acquiring Competences for Sustainable Development and Social Responsibility

The global challenges that Russian engineering education is facing today urgently require adequate and prompt responses that would assure retaining its level of compatibility and global competitiveness of Russian engineering solutions and developments. Undoubtedly, there are qualitative changes and improvements in the Russian system of engineering education throughout all stages of educational process, starting from admission procedures, designing of educational programs and ending up with advanced training of engineers. The focus lies on the transition towards training competitive specialists with the abilities, skills and knowledge required today and sufficient for future needs. The problem of listing the "right" set of learning outcomes and ability to develop such competences within the training process upon graduation from the engineering educational program has emerged quite a while ago; however, the solution is still far from the final state. The reasons why any problem appears and exists (and this problem in particular) are the objective and subjective contradictions that occur due to the inevitable changes in nature and all spheres of human activities: in politics, economics, culture, education, engineering, technology and many others. When it comes to the objective contradictions that led to the emergence of a problem of engineering graduates' competences formation, first and utmost, we need to focus on the contradiction between the philosophical concept of education and the applicative definition of a competence. Education as an act of knowledge consumption can be received without introduction of dynamic practical activities to the educational process. But at the same time, competences as a body of knowledge, skills and attitudes, despite its incorporation in the educational knowledge basis, cannot be formed without a solid, if not a prevailing, practical part of education. In terms of developing particular competences concerning Sustainable Development and social responsibility it means that the educational models and teaching and learning methods should seek for a practical application of these principles within the study process, whether it would be a study project that relates to or includes sustainability principles or it would be extra-curricular activities aimed at broadening students' understanding of social responsibility of a professional and of an individual.

2.1 Responsible Resource Management (RRM): Educational Perspective. Project Objectives

To the credit of modern Russian engineering education it is worth mentioning that training of socially responsible graduates became a notable trend. This ongoing trend is enhanced and supported by the requirements of Federal State Educational Standards, real academic activities within development and implementation of educational programs, curriculum requirements of several courses and disciplines, and, rarely, by the scientific research. The process of developing competences among future graduates is realized within study programs and requires from students acquisition of fundamental knowledge and skills to be applied in practice [4]. Usually it implies providing ordinary and well known conditions: qualified scientific and pedagogical staff, modern facilities, good connections with employers (cooperation with industry).

National Research Tomsk Polytechnic University, being one of the top technical universities of Russia, understands the need for adapting the existing educational model to the arising level of worldwide concern for sustainability and, therefore, has started several initiatives on applying principles of sustainability to the engineering education. One of these initiatives is the on-going applied interdisciplinary research project "Responsible Resource Management (RRM): Educational Perspective" executed by TPU Institute of Humanities, Social Sciences and Technologies.

The key objectives of this Project are to create the scientific basis for RRM encompassing ideas and methods of Technology Assessment and Responsible Research and Innovation (TA & RRI) and to modernize the process of engineering education in order to foster specific professional competences in the field of RRM and sustainability mindset of an engineer.

The research part of TPU project is based on a profound analysis of the existing methods of TA & RRI widely disseminated by Prof. Dr. Armin Grunwald and his team in the Institute for Technology Assessment and Systems Analysis (ITAS) [5]. TPU, in close collaboration with ITAS team, plans to develop methods and models for the design and evaluation of interdependent responsible resource utilization.

The Department of Management and Technology in Higher Professional Education, TPU, in its research activity focuses on the latter objective and develops various methods for the introduction of RRM to the education of future engineers.

The educational part of the project is aimed at formation and enhancement of specific competences of engineering graduates. It includes best practices analysis of the sustainability-driven university education in developed countries; analysis and expert assessment of the advanced teaching and learning methods introduced by top technical universities; analysis and modernization of the existing Russian competences model of future engineers and modernization of the educational process of TPU.

2.2 Responsible Resource Management (RRM): Educational Perspective. Project Outcomes

Among the core outcomes of the project are the following:

1. A list of specific educational environments that foster sustainability mindset of staff and students and allow to learn, experience and apply the principles of RRM to the professional activity of an engineer; an action plan for creation and/or development of these environments at TPU;
2. An updated graduates' competences profile of a responsible engineer addressing RRM competences; a model for monitoring and assessment of students' competences level;
3. A set of teaching and learning methods that will allow fostering of the identified competences (including Project-based and Problem-based learning, practice-oriented learning, interdisciplinary projects, expert seminars, smart-education, gamification, etc.);

4. Specific training programs for faculty members and administrative staff aimed at fostering their sustainability mindset and advancing their teaching and learning techniques;
5. Development and introduction of specific courses on RRM for undergraduates' and graduates' curriculum of all TPU study programs and a new master program on RRM.

3 Specific Learning Environments for Fostering Students' Sustainability Mindset

Development of the engineering education content includes the following points: providing profound fundamental nature of scientific knowledge in engineering education and engineering activities; ensuring the development of professional innovative thinking; providing complex training for innovative activities (ability performance). An important role in the content of engineering training plays the fundamentalization of engineering knowledge and engineering; development of fundamental laws of design and development of artificial environment: synergy, TRIZ, CALS-technologies; increase of interdisciplinary knowledge that provides innovation in problem situations; development of methodological culture: professional, cognitive, communicative and axiological activities; learning of natural science and humanities, transition on this basis to complex criteria: capacity, efficiency and quality of the designed artificial environment. However, as mentioned above, today it is more common for universities to focus their efforts on developing competences rather than mindsets of future engineers. Apart of other considerations a necessary condition to form/change students' mindsets is that higher education institutions need to develop Specific learning environments.

In the framework of the RRM Project a thorough analysis of world's best practices in identifying and developing specific learning environments has been conducted, which allowed to select most challenging and vital types of environments listed below:

1. Environment for Sustainable Development, including
    - Ecological (greening) environment
    - Social responsibility environment
    - Lean production environment
2. Creative environment
3. Entrepreneurial environment
4. Project based learning environment.

For instance, according to previous expert studies [6], in order to develop ecological outlook (ecological culture) of engineering students it is necessary to create a specific environment with particular characteristics (feature indicators), as shown in Table 1. The table indicates a necessary level (in percentages) of each feature indicator (rows) needed to achieve a certain level of ecological environment development (columns) according to experts' evaluation.

Table 1. Features of HEI ecological environment and indicators of the environment development level.

Feature	Development level of the environment			
	High level	Average level	Low level	Critically low level
Percent of students and faculty involved in ecological actions, %	61	39	19	8
Percent of scientific and academic actions in ecological engineering, %	39	26	15	6
Percent of university departments meeting the requirements of ecologically friendly environment, %	75	51	27	8
Percent of graduates using ecological competences in their professional occupation, %	76	54	27	10
Percent of students' papers (projects) directed at solution of ecological problems, %	34	20	9	4

Experience of Lappeenranta University of Technology (LUT), Finland, could be an illustrative example of implementing holistic approach for ecological environment development at an HEI [7]. Lappeenranta University of Technology encourages all its departments and even infrastructural units, such as restaurant and student cafeteria, to raise cautiousness in terms of responsible resource management, to lower the use of natural resources and/or to provide alternative power resources for its activities, etc. All staff members of the university are encouraged to take personal actions supporting the sustainability principles, for instance, staff members receive free service for their bicycles or special benefits for sharing a car ride with their colleagues to lower pollution. It is expected that each interdisciplinary project run by several departments suggests solutions for the ecological challenges that our society faces. A holistic education requires not only greening study programs, but involves greening the campus [8]. To support this process the university elaborates corresponding policies, norms and memorandums on ecomanagement, environmental ethics and alternative resource production for its operation, participates in various international agreements, consortiums and competitions on green campus and resource management. Such a wide spectrum of supporting activities of the university inevitably leads to the creation of a specific environment at the campus, where every action of staff members and students is inspired by the idea of eco-friendliness and sustainability. Therefore, a specific ecological mindset is fostered during the educational process, which provides the support for better and faster formation of the competences that involve principles of sustainability, such as, for instance, the ability to foresee, predict and analyze possible consequences of taken professional decisions.

Another important task of engineering training within the new-type industrialization that seeks not only for profitable decisions and in-demand products, but also for the responsible resource management and sustainability in decisions and actions, is the development of innovative creative thinking. Innovative thinking is an integrated set of creative, strategic, systemic and transformational thinking activity based on the laws of interdisciplinary knowledge:

- creative thinking: interdisciplinary knowledge, theory of the development of engineering solutions, multi-criteria formulation and solution of innovation problems, heuristics;
- strategic thinking: strategic management, synergy and the theory of self-organization;
- systemic thinking: systemic approach, system model, morphological analysis, systemic genetic analysis, systemic functional analysis; transformational thinking: self-management, CALS-technologies, organizational culture.

The key objective of a creative environment is to develop certain conditions for the enhancement of professional and creative competences for finding and executing breakthrough ideas that are competitive on global market, for formation of an overall creative culture and approach to professional activity. At the same time such an environment has to consider students' and teachers' individual psychological characteristics and students' dispositions towards certain professional area. At engineering HEIs these could be the dispositions towards technical engineering (technician, design engineer, researcher, programmer, operator) or social engineering activity (manager, economist, ecologist, sociologist).

In order to assure the development of creative innovative environment at universities European University Association (EUA) launched a project – Creativity in Higher Education – with support from the European Commission in the framework of the Socrates Programme (2006–2007).

The Project addressed the question of how creativity and innovation can be enhanced in higher education. There were 33 universities grouped into four networks working on the two core objectives of the project:

- To foster the development of creativity in European higher education institutions through good practice related to four network themes.
- To contribute to developing and improving institutional culture of creativity.

The aim of the project was to search for ways to develop creativity in higher education and scientific research by enhancing the educational and research environment and the connection between higher education institutions and public and private partners, as well as to identify specific institutional structures and processes that could promote creativity within the study process [9].

When speaking of a project-based learning environment it should be noted that the essential point in training engineers is to use the most updated global information resources for learning. At the same time it is important to implement a wide variety of methods to form cognitive and professional activity and to develop personal qualities: benchmarking, case studies, personal and professional development training, business training; organizational and business activity-games; problem-and project-based learning; creative workshops; design sessions; interdisciplinary projects; projects on the real customers' needs. The major direction of engineering education development in this respect is the special organization of student's work throughout the period of study at university in complex multidisciplinary teams, students' involvement in creative activities, maintenance of their mass participation in research, creation of purpose-based education. All these steps should create favorable preconditions of evolutionary transition in the engineering education from the educational ("the school of memory") to the research and educational processes. Nowadays, the educational process can be presented as a system of workshops led by creative, skilled and prominent researchers and leading engineers. The updated community of students, competitors for bachelor's and master's degree and engineering status, post-graduate students and people working for a doctoral degree form creative teams, a kind of scientific school capable of maintaining the continuity of cognitive activity, awareness of the world and the individual's place in it, ideals, values and objectives of the scientific and engineering work.

A prominent example of this specific environment is Aalborg University, Denmark. The uniqueness of this university arises from its foundation. The university was meant to assure a point of growth for the industrialized region of Denmark by its education and research conducted in close collaboration with the industrial sector of the region. As a result, all of the educational programs of AAU starting from its founding in 1974 have been structured upon Problem-based learning (PBL). The AAU PBL Model is acknowledged on national and international levels by universities, research organizations, students and industrial partners as an efficient and advanced educational model.

The organizational issues of PBL implementation are supported by the following actions:

- A university development strategy based on PBL model and knowledge cooperation;
- Supporting institutes within the structure of university: PBL Academy, PBL Laboratory;
- 50% of semester credits dedicated to students' project work and another 50% of semester credits dedicated to 3–4 courses supporting the project;
- An introductory course "Methodology of Project work";
- A combination of supervisors: internal and external (mostly, from industry);
- Events supporting and activating students' project work (Solution Camp, Wofie);
- Match-Making Center for establishing connections with stakeholders;
- Infrastructure with work and recreation spaces for students' project work.

Creating and supporting the development of a certain specific environment or several environments at an HEI allow to enlighten the traditional educational process with providing not only the knowledge and competences of a future specialist, but also fostering and deepening these competences by developing specific mindsets of students – the mindset that allows them to better understand their profession, their social status and their responsibility for taken decisions.

The RRM Project proposes to create and implement a set of actions for TPU faculty, administrative staff, students and other stakeholders, that would result in development of the 4 specific environments stated above. The set of actions concerns the educational process, the campus, the extra-curricular activities and events, the collaboration between the university and industry, and other areas of action that are vital for the development of HEI environment.

4 Concept of Responsible Education

The current TPU research project builds a bridge between training a responsible engineer and taking the responsibility for his/her education, learning outcomes and future career on behalf of an HEI, including faculty and administration involved in the teaching process. This research serves as a basis for developing the concept of Responsible Education.

To develop such a specific environment at a university, to promote and foster changes, to ensure sustainability mindset of graduates it is necessary to fulfill at least three conditions:

- HEI should elaborate and follow the Code of Responsible Education (meet high ethical standards of social responsibility for the quality of university training and competences of graduates);
- Scientific and pedagogical staff should feel and take social responsibility for the results of their work;
- HEI should create conditions for students, allowing them to constantly participate in different activities (projects and events) and assess the social impact of the solutions and decisions taken by them or their colleagues.

Referring to the main idea of the Code of Responsible Education of an HEI for the quality of graduates' training, first of all, should be noted a compulsory requirement to be included in the code: social responsibility of an HEI for the activities carried out and the results obtained by HEI graduates. In other words, the university has to take responsibility (at least moral) for the actions of its graduates, which have led to negative social consequences.

This thesis is quite controversial, as graduates act and make decisions based not only on their learning outcomes and experience acquired at particular university. In this case, of course, we should not exclude the impact and influence from outside (relatively speaking, streets), family, school and even kindergarten. However, one cannot disagree with the fact that when a person commits an act with negative social consequences, great responsibility (more informal) typically falls on the family. University, school, community at large, like streets, and, especially, kindergarten keep silent and shy away from their contribution to the formation of his/her personality. At the same time, if a person is famous, has had a distinguished career, made scientific discovery, became the winner of prestigious awards, all these social institutes take great merit to themselves for the formation of his/her personality, use his/her name for advertising purposes, and are proud of having links and benefits from this fact in all possible ways. It happens regardless of time passed and the degree of their participation in the process.

In many national and foreign universities we see galleries of portraits of outstanding graduates and alumni, alluding to the fact that their success has been the result of studying at these universities. Even world university rankings (particularly, Shanghai ranking [10]) contain such indicator as "Nobel Prize laureates among HEI alumni", although taking into account the year of graduation from the university. And there is not a word about the alumni, whose activities and decisions (political, economic, engineering and other) have led to negative social consequences, consumption of exhaustible resources, large number of deaths and troubles.

In this regard, it seems appropriate to develop a framework for launching a trend of Responsible Education, which will enhance the quality of training and successful implementation of the principles of Sustainable Development for the benefit of present and future generations.

5 Conclusion

Education, namely the engineering education, plays a key role in understanding and responding to the environmental and societal challenges through fostering specific competences, attitudes and actions of future engineers that will serve for the purpose of Sustainable Development of the society. However, competences as a body of knowledge, skills and attitudes cannot be formed without a solid, if not a prevailing, practical part of education.

Educational models and teaching and learning methods should seek for a practical application of the sustainability principles within the study process, which can be executed in a form of a study project that relates to or includes sustainability principles or in various kinds of extra-curricular activities aimed at broadening students' understanding of social responsibility on professional and personal levels.

The TPU concept of Responsible Resource Management and its introduction to the basis of engineering education can become one of the drivers for Sustainable Development of engineering and society at large. Today it is more common for universities to focus their efforts on developing competences rather than mindsets of future engineers. Higher education institutions need to develop specific learning environments in order to foster sustainability mindset of staff and students and allow learning, experiencing and applying the principles of RRM to the professional activity and everyday life.

The RRM concept is aimed at formation and enhancement of specific competences of engineering graduates in line with the principles of Sustainable Development and features a holistic approach to the sustainability-driven university education through assuring the development of specific learning environments at university, fostering staff's and students' sustainability mindset, application of advanced teaching and learning methods, taking actions towards modernization of the existing Russian competences model of future engineers and modernization of the educational process of TPU.

An ability to foresee the consequences of taken professional decisions and act responsibly is one of the core competences of a professional engineer demanded by modern society. Sometimes organizations produce negative impacts without realizing it, and universities as well. However, typically universities educate students and take merit only for their achievements and accomplishments, whereas the actions of their graduates, which have led to negative social consequences, are hardly ever mentioned by HEIs. The concept of Responsible Education encourages looking at social sustainability not only from the perspective of training responsible specialists, but from the point that universities have to take responsibility (at least moral) for the consequences of their graduates' actions.

New models for sustainable education proposed by the Tomsk Polytechnic University Responsible Resource Management project and the concept of Responsible Education will contribute to changing the mindsets of future generations beginning at an early age then fostered through formal education at undergraduate, graduate and professional levels.

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Recruiting and Developing Academic Leaders

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Abstract. The overall success of any organization is greatly influenced by effective leadership. For effectiveness, leaders need to possess competencies, some of which are general and some specific. However, universities, particularly in developing countries, have traditionally appointed academic leaders based on seniority in the academic rank regardless of whether or not the candidates have proven leadership competencies. Using 360° assessment of the behavioural competencies of deans who were recruited and developed using the leadership competency model, and those who were recruited using the traditional approach of voting by colleagues over a period of three years, it was found that on average the former performed better than the latter. It was concluded that recruiting and developing leaders based on an academic leadership competency model provides effective academic leadership.

Keywords: Competence · Competency model · Academic leadership · Academic sector

1 Introduction

1.1 General

Academic leadership "is the act of building a community of scholars to set direction and achieve common purposes through the empowerment of faculty and staff" [1]. For effectiveness, leaders need to possess competencies, some of which are general and some specific to the academic sector. However, in many universities, leadership positions at the level of faculty deans are held by faculty members who willingly give up all teaching and research activities and become full-time administrators. Traditionally, these deans are voted into their positions by colleagues in their schools/colleges based on their seniority. Depending on campus policy, it may be for a limited time period. Most deans return to the faculty when their terms in office have expired. For them, leadership in the dean's position is complicated by the desire to bring accomplishment and excellence to the college or school [2] while keeping in mind that they will return to the faculty that they are shaping. For those deans who do not have to return to the faculty, and are normally recruited using a rigorous recruitment process, attention to leadership is more managerial/professional in nature.

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1.2 Historical Development of Academic Leadership

Traditionally, around the world, academic departments have been led by a single professor of a discipline related to the offering of the department. Such professors were the heads of departments (HoDs) and held these posts permanently. Given the mastery of knowledge in their disciplines, the professors were mostly influential people within the institutions, and so were the HoD positions that they held. However, this arrangement has gradually changed over time at all universities as the result of new dynamics in higher education. This change has resulted in the erosion of the prestige of being an HoD and, more importantly, the ability of HoDs to exert academic leadership; and as the time and opportunity for teaching and research was steadily eroded, senior academics have been opting out of the HoD role [3]. Furthermore, in general, HoDs feel unappreciated and regard themselves as relatively junior functionaries performing a mostly administrative role [3]. As the result of this state, a number of universities have made it mandatory for senior academics to serve as HoDs when called upon to do so.

Within the academic context, defining the academic leadership position is a complex task. It is often the case that academic leaders get voted into a leadership position without much leadership training or experience, nor an understanding of what the demands and the complexities of the new role will be. They also do not take into account that they will have to change on many levels from an academic to an academic leader, which means that less time will be available to spend on their personal and academic lives [4, 5].

Developing a competency profile for academic leaders not only enables future development of relevant training programmes for academic leaders, but will also give universities the opportunity to ensure that their leadership is of the highest quality possible. Having an outline of which skills and competencies are needed will help a selection panel to choose the most suitable candidate when appointing new academic leaders in the future.

Although many professions within universities operate within a stable institutional context [6], the leaders of these institutions need to be able to adapt to a constantly changing environment and external influences. These skills cannot be learned in a day or in a workshop but need to be developed over some time.

Another challenge academic leadership is often faced with is the ambiguity in which they need to lead. Academic leaders must be able to adapt their leadership style when working with the different constituencies of the faculty and the university. A more facilitative leadership style is needed when working with faculty in the academic core and a more traditional line-authoritative style is needed when working with the administrative core [6]. Very often academic leaders need to work with both types of employees which adds pressure on developing their own management skills.

There is also constant tension in pursuing academic goals and having the obligation to perform administrative duties. “Having insufficient time to remain current in my discipline” is the number one stress for HoDs and ranked third for Deans [7]. The balance between pursuing academic goals and performing administrative duties leads to time constraints. These time constraints add to the challenge to adapt the new role and its environment, to master newly acquired skills and to function on operational and strategic levels.

One should not be under the illusion that the training of competencies alone will be the answer to addressing this need of leadership. People's leadership abilities and willingness to lead are influenced by different factors, e.g., family, friends, level of education and previous leadership roles at schools [1]. Indeed, these qualities often make far better candidates than training alone, as Conger [8] explains: "If experience is such an important teacher, and motivation to lead is rooted in one's past, and leadership skills are indeed so complex and related to one's work and past, what role can training hope to play?" (p. 34).

Generally, academics do not aspire to do the job of a leader. In a study done by Oliver-Evans [9] it was reported that 70% of the HoDs did not want to do the job. The majority of HoDs see themselves as overburdened in a thankless job that detracts from their scholarly careers, in which their status, and thus their ability to implement leadership, has been eroded, and for which there is inadequate support from their administrative and academic colleagues. Most damaging is the perception that they may have lost the respect of their peers: their colleagues are certainly grateful that the job of HoD is being done, but they generally do not admire or respect the position.

Based on this background, this paper compares the behavioural performance of deans who were recruited using the traditional approach with those who were recruited using a rigorous process based on a leadership competency model.

2 Competence and Competency Model

2.1 Competencies

Competencies provide a framework for human capital and help organisations focus their employee development in order to gain a competitive edge [10]. Competencies have become a benchmark of organizational effectiveness as organisations realize the intellectual assets their employees are. When an organisation is open about the competencies they require their staff to have, it is easy for employees to understand what they need to work towards to succeed in their careers [11]. Clearly defined competencies will help an organization to put its business imperatives and objectives into performance requirements for its employees [12].

In order to compile competencies that can be easily understood, it is important to understand what is meant by the term "competence"

Klemp [13] defines competence as a generic knowledge, skill, trait, or motive of a person that is causally related to effective behaviour, and must be manifested in a variety of ways in a number of situations. The term "causally related" means that there is evidence which indicates or suggests that possession of the characteristic (e.g., knowledge, skill, trait, or motive) precedes and leads to effective performance [13].

Parry [14] defines competence as "a cluster of related knowledge, attitudes and skills that affect a major part of one's job that can be measured against well-accepted standards and that can be improved with training and development (p. 18).

It is clear from these two definitions that all competencies include attributes/abilities, knowledge and skills.

2.2 Competency Model

A competency model is a functional categorization of separate competencies that tend to occur simultaneously in situations where effective performance is demonstrated.

2.3 Uses of Competency Models

Campion et al. [15] summarised a list of several uses of competency models based on a literature review. Competency models can be useful for selection purposes because competencies of top performers have been identified and new joiners can be measured against a specific profile. Having a competency model in place enables management to identify developmental areas where employees need training. For example, executive development, coaching programs and 360° surveys are often built on a competency model foundation [15].

Models that depict levels of competency proficiency, job grade and pay levels can be used as tools around which to structure appraisal instruments to establish promotion criteria [16, 17].

Employee information can be easily managed by using competency models to record and archive employee skills and training. By identifying and measuring current competencies, a higher retention rate of critical skills can be achieved, enabling the organisation to achieve its organisational objectives [18, 19].

Developed competency models can assist organisations with change management interventions by providing the ability to align the way in which employees are trained, assessed, selected, promoted and rewarded [20].

3 The Competency Model of the University of Botswana

A competency model should have a combination of universal as well as job specific competencies [21]. When a competency model is developed for a specific organisation, it has more relevance because employees have given personal inputs for defining the competencies [21]. Personal involvement in a process will develop a sense of ownership, which in turn will make the implementation process easier.

The leadership competency model of the University of Botswana was developed by an HR Consultancy Firm and is generic in the sense that it caters to both academic and support leadership positions. The model has seven competencies and 29 leadership abilities (Table 1). Having decided to employ the competency model for recruitment of all leadership positions in 2006, all candidates for various leadership positions were given feedback on their performance at the interviews. Generally, these candidates were informed of the competencies in which they were strong and those in which they were weak. Successful candidates undergo training to enhance the competencies over which they showed weakness during recruitment.

Table 1. Competencies and corresponding leadership abilities

Competency	Leadership ability/Behaviour
Development of a core set of values and vision	The ability to clearly identify the values and beliefs upon which one's actions are based
	The ability and willingness to act on one's beliefs
	The ability to develop a clear direction for the future and strategies for bringing about necessary changes
Effective communication	Ability to identify the unspoken problem that lies beneath the surface of verbal communication
	The ability to consider multiple perspectives
	The ability to use language which is clear, direct, honest and respectful
	The ability and willingness to provide an explanation for decisions made
	The ability to depersonalize the problem/situation in order to state it in objective terms
	The ability to utilize appropriate metaphors and analogies
	The ability to communicate in multiple forums (memos, newsletters, formal meetings)
Creating a positive climate	The ability to interact comfortably with a diverse variety of people, including gender, age, and ethnicity, among others
	The ability to establish a high-trust environment
	The ability to develop a sense of empathy
	The ability to motivate and inspire others
Facilitation and collaboration	The ability to share responsibility and authority with others
	The ability to identify potential relevant common interests
	The ability to create opportunities for people to form partnerships through shared knowledge
	The ability to form teams that understand the vision and strategies
Problem solving and risk taking	The ability to examine situations from a variety of perspectives
	The ability to encourage people to both generate and share new ideas, and to explore potential solutions and their consequences
	The ability to involve people in making critical decisions
	The ability to demonstrate a willingness to propose direction and action
Reflection and analysis	The ability to step back, observe the situation, identify multiplicity of issues, and interpret the underlying dynamics
	The ability to assimilate and accommodate new information

(*continued*)

Table 1. (*continued*)

Competency	Leadership ability/Behaviour
Results orientation/initiative and accountability	The ability to plan, coordinate and oversee processes and functions to achieve optimal results within the required time frames
	The ability to schedule tasks, meetings and activities to correspond with institutional schedules and operational cycles
	The ability to adhere to pre-planned schedules and operational requirements
	The ability to direct activities and endeavour to achieve appropriate outcomes
	The ability to understand the unit's objectives and direct collaborative effort to attain them

4 Methods

Behavioural competencies of seven faculty deans at the University of Botswana, three who were recruited using the traditional approach of voting by colleagues in the faculty, and four who were recruited based on a leadership competency model, were compared for a period of three years through the use of 360° assessments. Data were collected from the annual performance reports of staff from the department of Human Resources after obtaining consent from the relevant deans on condition that they remain anonymous. The behavioural competencies included: development of a core set of values and vision; effective communication; reflection and analysis; facilitation and collaboration; creating a positive climate; problem solving and risk taking; and results orientation/initiative and accountability.

The behavioural aspect of the annual performance was based on the 360° assessment by: Self, Overseer, Peer (average score of 3 peers); and Subordinates (average score of 3 subordinates). The three peers and three subordinates were randomly selected.

Scores were based on a scale of 1–5 with the following percentages 1 (32%); 2 (49%); 3 (64%); 4 (79%) and 5 (100%). While the scores of Self and Overseer were based on these percentages, the scores of Peer and Subordinate were the average of the three scores which is a combination of 32%, 49%, 64%, 79% and 100%. For instance, if Peer 1 scored 49%, Peer 2 scored 64% and Peer 3 scored 79%, the average score was (49 + 64 + 79)/3 = 64.

5 Results

Table 2 shows the annual performance for years 2006, 2007 and 2008 of the four deans who were recruited using the University of Botswana Leadership Competency Model, while Table 3 shows the performance the three deans who were recruited using the traditional approach over the same period.

Table 2. 360° assessment of behavioural leadership aspects of deans recruited using the competency model

Competency	Overseer				Peer			Subordinate			Self		
Year of assessment		06	07	08	06	07	08	06	07	08	06	07	08
Development of a core set of values and vision	D1	64	79	79	76	86	86	79	86	93	79	79	100
	D2	79	79	100	81	93	93	93	93	100	79	100	100
	D3	64	79	79	76	76	79	79	81	81	79	79	79
	D4	64	79	79	76	81	86	81	93	86	79	79	100
Effective communication	D1	79	79	79	93	93	93	86	86	100	79	100	100
	D2	79	100	100	93	93	100	93	100	100	100	100	100
	D3	79	79	79	86	81	93	93	93	93	79	79	100
	D4	64	79	79	81	81	79	86	81	93	79	100	100
Creating a positive climate	D1	79	79	79	79	86	93	93	93	100	79	100	100
	D2	79	79	79	86	81	93	100	93	100	100	100	100
	D3	79	79	79	81	81	86	93	86	86	79	79	100
	D4	64	79	79	81	86	86	93	86	93	79	100	100
Facilitation and collaboration	D1	79	79	79	76	81	86	81	93	93	79	100	100
	D2	79	79	100	86	86	100	100	93	93	100	100	100
	D3	64	79	79	79	86	81	86	86	81	100	79	79
	D4	64	64	79	79	86	86	81	93	100	79	79	100
Problem solving and risk taking	D1	64	64	64	76	86	86	81	86	93	79	100	100
	D2	100	100	100	100	93	100	93	93	100	100	100	100
	D3	64	79	79	86	81	81	93	86	93	79	100	100
	D4	64	64	79	76	76	93	81	79	81	79	79	100
Reflection and analysis	D1	64	64	79	76	86	86	93	86	86	79	100	79
	D2	79	100	100	86	93	100	93	100	93	100	100	100
	D3	64	79	79	81	79	86	86	86	93	79	100	100
	D4	64	64	79	86	86	81	93	86	93	79	79	100
Results orientation/initiative and accountability	D1	64	64	79	79	81	81	86	81	93	79	79	100
	D2	79	100	100	86	93	100	93	100	100	100	100	100
	D3	64	79	79	81	93	93	86	93	93	79	100	100
	D4	64	79	79	81	81	86	86	86	93	79	100	100

D1–D4 means Dean1, Dean2, Dean3, and Dean4
Years 06–08 mean 2006, 2007 and 2008

The various combination of scores possible for Peers and Subordinates make the deans' averages range from 49% to 100%. Specifically, the scores are 49, 54, 57, 64, 66, 76, 79, 81, 86, 93 and 100.

Table 3. 360° assessment of behavioural leadership aspects of deans recruited using the traditional approach

Competency	Overseer				Peer			Subordinate			Self		
Year of assessment		06	07	08	06	07	08	06	07	08	06	07	08
Development of a core set of values and vision	D5	64	64	79	64	69	69	69	76	76	79	79	79
	D6	49	49	64	54	54	64	64	66	64	64	64	79
	D7	64	79	79	66	64	66	76	66	79	79	79	79
Effective communication	D5	49	49	64	64	57	57	54	66	64	64	64	79
	D6	49	64	64	54	64	66	57	54	64	64	64	64
	D7	49	49	64	57	54	57	66	57	57	64	64	79
Creating a positive climate	D5	64	64	64	66	57	64	57	57	66	64	79	79
	D6	64	79	79	66	79	64	79	79	81	79	79	79
	D7	49	64	64	76	66	66	64	57	66	64	64	79
Facilitation and collaboration	D5	64	64	64	66	76	66	76	64	66	79	79	79
	D6	64	64	79	76	64	64	66	66	66	64	79	79
	D7	79	79	79	81	79	79	81	81	79	79	79	79
Problem solving and risk taking	D5	49	49	64	54	57	54	57	64	57	64	64	79
	D6	49	64	64	57	57	66	64	66	66	64	64	64
	D7	64	79	79	66	64	64	76	76	79	79	79	79
Reflection and analysis	D5	64	64	64	66	76	66	66	66	64	79	79	79
	D6	64	64	64	64	64	66	64	86	64	64	64	64
	D7	64	79	79	66	64	76	57	64	64	64	64	79
Results orientation/initiative and accountability	D5	49	49	64	64	66	66	57	64	64	64	64	64
	D6	49	49	64	54	57	57	64	66	64	64	79	79
	D7	64	79	79	66	79	79	66	76	76	79	79	79

6 Discussion

The four deans who were recruited using the University of Botswana Leadership Competency Model received a comprehensive report of their performance at the interviews. These reports detailed the competencies with which they had strength and the ones where they were weak.

On starting their duties as deans, they had discussions with their overseers on how to leverage the competencies in which they showed strength and established training programmes to address the competencies that they were weak in. Over time, these deans showed progressively superior performance in all competencies as shown in Table 2.

On the other hand, the three deans who were recruited using the traditional approach of been nominated by their peers based on seniority were not afforded the training approach similar to the one explained above because their strengths and weaknesses were not determined when they were appointed into their positions. Although they often attended leadership development programmes, these were to targeted to identified areas of their weakness. As shown in Table 3, on average, the performance of the deans recruited using the traditional approach did not improve with time and were, on average, inferior to that of the deans recruited and developed using the leadership competency model.

7 Conclusions

The importance of effective leadership for effective performance of any organization hardly needs to be emphasized. This is even more important for Higher Education Institutions (HEIs), which are complex organizations with mandates comprising of multiple objectives. Historically, leadership positions in HEIs have been occupied by senior academics, often professors whose stature and superior knowledge of their disciplinary areas accorded them respect of staff in their units (departments/schools/faculties/colleges).

However, over time, the dynamics of HEIs have required a different type of a leader, who has competencies in the various areas of leadership and management. For effective leadership, HEIs need to recruit and develop their leaders using approaches that identify their strengths and weaknesses in the appropriate competencies for their positions and then provide training to enhance the areas of identified weakness.

This three-year study compared the performance of seven deans, four of whom were recruited and trained/developed using a Leadership Competency Model and three using the traditional method which is based on seniority without training/development. Overall, the performance of the former was much superior to the latter. Within the limitations of this small study, it can be inferred that recruiting and developing academic leaders using an appropriate competency model leads to effective academic leadership. However, this type of study on deans needs to be repeated using larger samples to confirm the inference.

Given that the current study looked only at the positions of deans, it is recommended that this type of study be extended to cover all academic leaders in order to provide data for appropriate statistical analysis.

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Excellence in Engineering Education

Introduction to Section of "Engineering Education for a Smart Society": Section Entitled Excellence in Engineering Education

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The World Engineering Education Forum and the Global Engineering Deans Council combined annual conference in November 2016 in Seoul, Korea, offered an excellent opportunity for engineering deans and educators, as well as industrial practitioners, to gather and learn some of the more recent developments in engineering education and practice. Many of the very best papers presented were assembled into this book, and this particular section focused on *Excellence in Engineering Education*.

There are many trends occurring in the transformation of higher education around the globe. One of these trends is the clear recognition that both interdisciplinary research and interdisciplinary engineering education will be required to enable the global engineers of the future to solve the most challenging global needs, e.g. renewable energy systems, sustainable cities, and the like. Dr. Andrea Dirsch-Weigand and her colleagues presented a nice paper on integrating interdisciplinary education and learning into the engineering curricula by incorporating interdisciplinary projects and experiential learning into coursework. We should encourage and expect to see more offerings like this at Universities around the world.

Another important area of research in engineering education is discovering how young students learn best and integrating those cognitive and metacognitive learnings into our engineering curricula. In order to enhance the capabilities of engineering students, Dr. Nur Fazirah Jumari and her colleagues at Technical University of Malaysia describe the use of cooperative problem based learning in their engineering curricula to develop metacognition. Along these lines, Dr. Katriina Schrey-Miemenmaa of the Helsinki Metropolia University of Applied Sciences collaborated with researchers across northern Europe to study the power of debate and "cross-sparring" and the role of self-evaluation in enhancing the quality of engineering programs.

Critically important technologies for the future development of the emerging smart society are computer programming and the development of the internet of things. Two papers in this session focused on this. Dr. Andi Sudjana Putra and her colleague from the National University of Singapore presented a paper on a collaboration between industry and academia in developing an "internet of things" design course for undergraduate engineering students. Dr. Nor Azlinda Azmi and her colleagues at the Technical University of Malaysia describe a How People Learn (HPL) framework for determining how to motivate students to learn computer programming.

Finally, Dr. Anne-Marie Jolly of the Polytechnic University of Orleans compares the program outcomes and institutional management frameworks used by the two major accrediting bodies in Europe: EUR-ACE and CTI.

All in all, these were excellent offerings representing the latest findings in engineering educational research.

Picking Low Hanging Fruits – Integrating Interdisciplinary Learning in Traditional Engineering Curricula by Interdisciplinary Project Courses

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Abstract. Setting up integrated interdisciplinary study programs is complex and expensive. This case study presents specific interdisciplinary project courses of the Technische Universität Darmstadt as an alternative practice for integrating interdisciplinary learning in traditional engineering curricula. Relying on the experience from 22 project courses for first year students and 22 advanced design projects for master students, the authors exemplify that a sequence of interdisciplinary projects in the bachelor's and master's program leads to a systematical development of interdisciplinary competences: competence in interdisciplinary team work and problem solving in the bachelor's projects and actual interface expertise for interdisciplinary design tasks in the master's projects.

Keywords: Interdisciplinary learning · Problem-based learning · Project-oriented learning

1 Introduction and Motivation

Faced with the complex and multi-faceted challenges for smart societies, e.g. challenges of climate, energy, population, nutrition, water, health and safety, and the requirement for social, ecological and economical sustainability, the need for interdisciplinary engineering education is indisputable.

But setting up integrated interdisciplinary study programs such as Energy Science and Engineering or Computational Engineering is complex and expensive. Thielbeer measured the information costs of a new study program accreditation to be 131 work days (Thielbeer 2008, 4). This included self-documentation of the university's

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module-descriptions, examination regulations, qualification of lecturers, etc. and excluded all efforts for the implementation of the study program. Therefore, the Technische Universität Darmstadt took an additional approach to integrate interdisciplinarity to all departments of the university: Monodisciplinary project courses were extended into interdisciplinary project courses - a rewarding, uncomplicated and easy way to embed interdisciplinary learning in engineering education curricula.

Relying on five years of experience from 22 interdisciplinary project courses for first year students in 12 departments and 20 years of experience with 22 interdisciplinary advanced design projects for master students of thermal process engineering in a mechanical and process engineering department, we present the interdisciplinary project courses at the Technische Universität Darmstadt as an efficient alternative for integrating interdisciplinary learning in traditional engineering science curricula.

2 Objectives and Methods

In this paper, we exemplify project courses for interdisciplinary learning in the bachelor's as well as the master's program of the mechanical and process engineering studies at the Technische Universität Darmstadt. In the bachelor's project, we have analyzed the effect of project-based interdisciplinary learning on the self-reported development of a professional identity and the formation of professional competences including communication, intercultural and social skills as well as a cooperative mindset. The advantageous effects of interdisciplinary project teams are underpinned by a comparison of mono- and interdisciplinary project teams based on evaluation data of a project course with a total of 163 participants in 2012. For the master's project, we illustrate the impact of interdisciplinary learning on the development of professional interface competences and integrated technical knowledge. The case study is based on two project courses with a total of 119 participants in the years 2014 and 2015.

3 Results: Systematical Development of Interdisciplinary Competencies in Bachelor and Master Project Courses

According to the principles of evidence-based teaching and learning, the introduction of compulsory project courses as a specific form of active learning (Marra et al. 2014) in the mechanical and process engineering bachelor's program in 2007 was grounded on comprehensive experiences with project courses since 1998 and thorough empirical evaluations in 2006 (Möller-Holtkamp 2007).

In 2012, the monodisciplinary project courses for first year students became interdisciplinary with three objectives:

- On the one hand, the interdisciplinary study projects were to give mechanical and process engineering students from the very beginning a discipline-specific identity contrasting them with the profiles of other disciplines.
- On the other hand, the interdisciplinary study projects should support students in developing generic competences such as communication, team work, problem

solving and self-organization skills and in developing attitudes such as responsibility and appreciation of disciplinary diversity (Koch et al. 2017, 4).

- The third objective was to prepare students for the advanced design project in the master's program which has been interdisciplinary from its start in 1995.

Today, we can show that the sequence of interdisciplinary projects in the bachelor's and master's program leads to a systematical and gradual development of interdisciplinary competences, which are competence in interdisciplinary team work and problem solving in the bachelor's projects and actual interface expertise for interdisciplinary design tasks in the master's projects.

3.1 Definition of Interdisciplinary Competences

Interdisciplinary competences are a basic condition for interdisciplinary work in science and industry. Interdisciplinary work means cooperation of people from different disciplines (or even sometimes non-professionals) in order to reach a common goal or solution. Interdisciplinary cooperation can only be successful if co-workers define common goals, develop a common understanding of the problem(s) to solve, formulate common subjects, find a common language and agree on approaches, methods and individual contributions. The biggest challenges in interdisciplinary cooperation are consensus-building, finding a common language and managing group-dynamic processes that otherwise could lead to conflict or withdrawal of a group member (Defila and Di Giulio 2012, 4/5).

Therefore, the necessary interdisciplinary competences consist of specific techniques and methods on the one hand and adequate attitudes on the other hand. On the level of cognitive learning, these competences embed knowledge about and application of methods of consensus-building such as discussion, moderation and decision-making techniques and the ability to reformulate issues in a non-technical language and from a different point of view. On the level of affective learning, these competences include the awareness of the special interdisciplinary setting and its specific requirements and the valuing of mentalities and methods from other disciplines (Defila and Di Giulio 2012, 11/12).

The best way to teach and learn these competences is to offer learning environments where work in interdisciplinary teams can be experienced and reflected in practice. Interdisciplinary study projects implement exactly such settings. Technical, generic and interdisciplinary competences are equal learning objectives of this teaching and learning form.

From the work of Steinheider et al. (2009), we have a validated and reliable instrument to assess the awareness of interdisciplinary knowledge integration in project teams in academic and industrial settings. We adapted the proved instrument to assess the awareness of interdisciplinary knowledge integration in the project teams in our interdisciplinary projects for bachelor students.

The difference between interdisciplinary competences and interdisciplinary interface competences is that people with interdisciplinary interface competences are not only aware of the special requirements of team work in interdisciplinary project teams and know how to communicate, moderate and make sound decisions. In addition, they are able to structure, plan and coordinate their collaboration in a way that they take the maximum advantage of disciplinary diversity in their team. They, therefore, need additional advanced competences in project management and task design.

3.2 Acquisition of Interdisciplinary Competences in the Interdisciplinary Bachelor's Projects

The educational strategy behind the interdisciplinary study projects for bachelor and master students is the development of systemic and interdisciplinary problem-solving skills by active and practical learning from the very beginning.

Didactic Concept of Interdisciplinary Projects for Bachelor Students
The overall didactic concept of interdisciplinary study projects for bachelor students has been described in (Dirsch-Weigand et al. 2015; Pinkelman et al. 2015). Typically, first year students from engineering and natural sciences as well as from arts, social and human sciences form project teams of about 12 people to work on a complex set of tasks for one week. The task focuses on a real-life problem with societal relevance such as the global refugee problem, energy efficiency or urbanization. Interdisciplinary learning is ensured by a task assignment which forces students to make joint interdisciplinary decisions (Robertson and Franchini 2014). Since interdisciplinary problem solving is demanding for students in their first year, they are continuously supported by technical and team advisors. Technical advisors are academic staff from the participating departments and provide students with specialized feedback on the principle of "help for self-help". Team advisors are advanced students of pedagogy and psychology and have been trained and qualified intensively by the Centre for Educational Development. They enable students to engage in constructive and effective discussion, moderation, visualization, problem solving and conflict handling. At the help desk and in the expert interviews with professors, students can do further research for deeper technical information and discuss solutions.

A concrete example is the cooperation of the mechanical and process engineering department, the department of biology and the institutes of philosophy and political science in 2012 – one of five interdisciplinary bachelor projects in the mechanical and process engineering department since 2012.

In this study project, 506 students in 48 project teams developed integrated concepts in order to halt desertification. The concepts had to be based on an innovative fiber fleece, which enabled the application of appropriate plant seeds or cuttings and supported the germination and establishment of plantations. Ideally, the fleece should allow a profitable cultivation of crops, which had to be proven by a rudimentary business plan. At the same time, production and application of the product should be sustainable and authorized by the political participation of the concerned people. Due to this product, soil degradation should be halted, and the spread of agriculturally unusable and barren land should be prevented permanently.

In the first step, students chose a country where to apply the innovative "FloraPad". In this phase, students of political science held a position of professional leadership, whereas in the following investigation of ecological and climatic restrictions of the chosen region, the biology students could hold this position. Definitions of technical, chemical and biological capacities for the product and a first set of feasible product concepts were joint work of both mechanical and process engineers and biologists. The subsequent decision of which concept was to be refined and finalized was done conjointly by all disciplines in plenary, but philosophical criticism had a special importance because reflections on ethical, political, social, economic and ecological implications were part of the design rational. The students worked step by step collaboratively and switched from individual work to team work and vice versa. The 506 students were continuously supported by 36 technical advisors and 29 team advisors. Around fifty professors and industrial experts were available in expert interviews or as jury members for half a day. At the end of the week, all 48 student teams were successful to present a concept of “FloraPad”.

Effective Acquisition of Interdisciplinary Competences

Due to the different number of students in engineering and other studies, not all project teams in the 2012 project were interdisciplinary. Therefore, project evaluation data allowed for a comparison of mono- and interdisciplinary teams with $N = 163$ students after inconsistent responders were excluded (e.g. pure engineering teams reporting

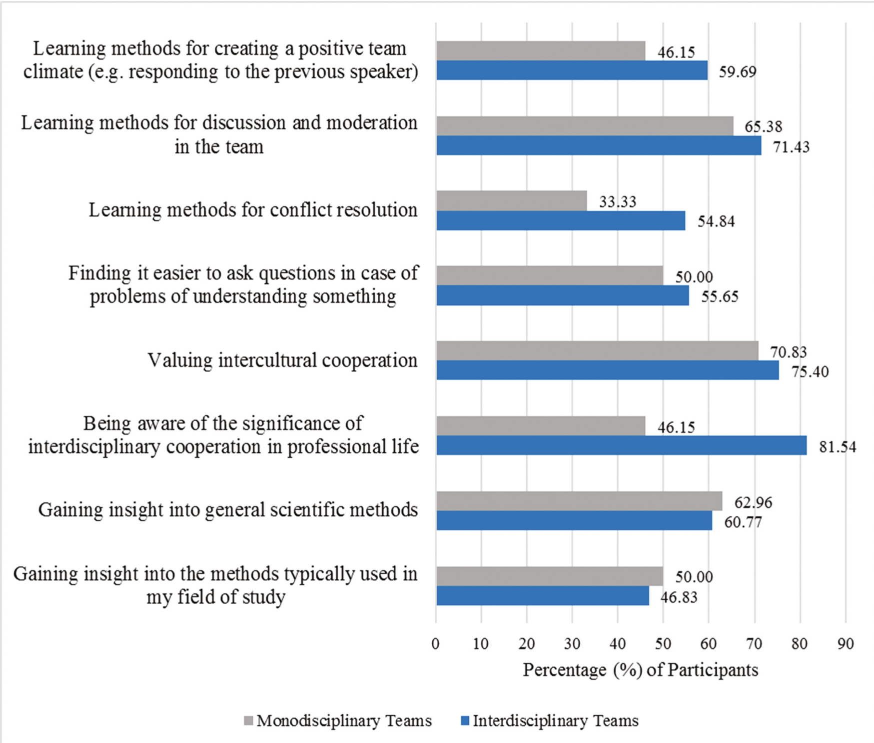

Fig. 1. Percentage of students agreeing to different learning experiences in the project (ratings lower than 2.5 on a 1–5 scale from 1 = agree to 5 = disagree)

themselves to be interdisciplinary). Of those, 135 students had been in interdisciplinary and 28 in monodisciplinary teams. Figure 1 shows percentages of students from inter- and monodisciplinary teams who agreed that they had certain learning experiences through the project (i.e. who gave ratings of 1 or 2 on a scale from 1 agree to 5 disagree).

As can be seen from Fig. 1, a slightly higher percentage of students from monodisciplinary teams agreed that they had achieved insights into specialist methods and common scientific methods through the project. A higher percentage of students from interdisciplinary teams, however, reported that the projects had inspired them to value interdisciplinary and intercultural team work. Additionally, a higher percentage of students from interdisciplinary teams agreed that they had acquired team work and communication competences (e.g. asking questions etc.). The acquisition of these interdisciplinary team work and methodical competences builds the foundation for the advanced design project in the master's program. Moreover, a higher percentage of students from interdisciplinary teams (78.03%) agreed that they had seen themselves in the team as a competent representative of their field of study compared to monodisciplinary teams (66.67%), suggesting that the interdisciplinary team work supported students' identification with their field of study.

Furthermore, the students' responses in interdisciplinary teams supported our assumption that the project provided appropriate conditions for successful interdisciplinary cooperation. Figure 2 shows the percentage of students from interdisciplinary teams who agreed to several items referring to the interdisciplinary collaboration in their team. As can be seen in Fig. 2, the great majority of students in interdisciplinary teams agreed that they had shared objectives and goals with their teammates and that they had developed a shared understanding of the project. Even more, most students agreed that they had been able to communicate well within the team.

Whilst we chose the results presented here to illustrate the successful implementation of interdisciplinary first year projects in mechanical and process engineering, similar results have also been found for other projects involving students from other engineering disciplines such as electrical engineering.

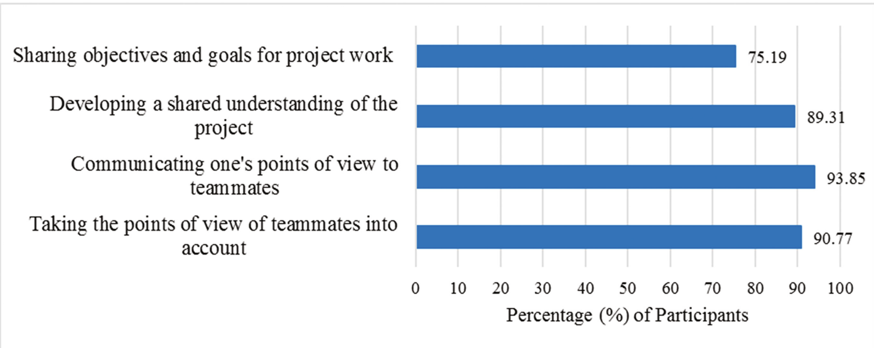

Fig. 2. Percentage of students in interdisciplinary teams agreeing to items assessing successful interdisciplinary cooperation (ratings lower than 2.5 on a 1–5 scale from 1 = agree to 5 = disagree); items adapted from (Steinheider et al. 2009).

3.3 Acquisition of Interdisciplinary Competences in the Interdisciplinary Master's Projects

Didactic Concept of Interdisciplinary Projects for Master Students

The overarching didactic approach to the master's projects is an Advanced Design Project (ADP) with two main learning objectives: the development of professional skills through team work and design skills through application. The teams are diverse and interdisciplinary including students from chemistry, mechanical and process engineering from TU Darmstadt, and students from chemical engineering from a university of applied science (Fachhochschule in German) in 2014 and additionally, American chemical engineering students in 2015. ADP is a bridge between typical course design projects and "real" industrial design projects. The project topic (typically a chemical plant) is developed with and supported by an industrial partner with real plant data. For example, in 2014, the project was the design of a bioethanol plant and in 2015, a sulfuric acid plant.

ADP is a two week, intensive project design course. Due to this nature and the scope required to design an entire new chemical process, ADP is taught as structured design with little room for variation and creativity in the plant design. The overall plant design is segmented into major tasks, and tutors develop specific tasks and goals (daily and project) that the groups must do and meet, e.g., on the first two days, they must complete a mass balance of the entire plant, usually with a given method, e.g., the Nagiev method for the mass balance. All groups are composed of approximately 5–7 students and are interdisciplinary with differing degrees of diversity (in regards to disciplines). Since there are only approximately five tutors for 60–70 students broken into 10 groups, groups are encouraged to talk with and collaborate among each other (especially for troubleshooting).

Effective Acquisition of Interdisciplinary Interface Competences

Development of the original assessment for 2014 is detailed in (Anders et al. 2014). Shortly, it assessed team competence, including students' ability to contribute to a group project, communicate well within the group, resolve conflicts, and plan, schedule, and assess the group's progress, and design competence, specifically their ability to find and evaluate different solutions, use of criteria to critically evaluate their progress and design, aptitude in carefully defining the problem, breaking complex problems down, and using networks and flowcharts to keep track of design variables. In 2015, open-ended questions about team and design competence were also included along with daily reflection questions. The closed-ended questions were assessed three times at the beginning, middle, and end of the two-week course. The 12 questions (6 – team and 6 – design) were compiled for both years and compared.

Analyses of the two projects have shown that teams with higher professional qualities produce higher quality design work. These professional qualities are interdisciplinary interfaces competences: the ability to work cohesively in an interdisciplinary group and design a plant that requires the knowledge and skill of different disciplines. The more diverse the group was (in terms of discipline), the higher were also their overall competences in interdisciplinary team work and design skills. Specifically, in 2014, students self-reported their team roles every day. Two of the groups reported more than one leader (for one day) compared to other groups and also had lower competences and final project scores. This indicates that the team was not effectively working together as evidenced also by their lower assessed team and design competences, which in turn affected their final project score.

At the end of the two-week course, 81.18% of students assessed themselves higher than 3.5 (on a 1–5 scale, with 5 being the most competent) for team competence. Overall, they perceived themselves to be competent in their ability for individual contribution, team work, communication, and conflict resolution (Fig. 3). Interestingly, half way through the course, students assessed themselves lower in all six team competence questions but most especially in conflict management (data not shown). This indicates, that there were conflicts within the team, but they were able to resolve them and communicate better by the end of the course.

Due to the structured design process in this course as described above, there is little room for creativity and variants in design. This can be seen in the answers to the question whether or not they had developed different solutions (12.16%), which in turn had a large effect on the average design. It is also interesting to note that over the course, students reported that they were able to integrate different perspectives into the design process.

Here, we are able to show that based on the foundation of first year interdisciplinary project courses master students have a high competence in interdisciplinary team work at the start of the course (Fig. 3, Avg. Team (pre) 74.34%) and further develop this competence through ADP (Fig. 3, Avg. Team (post) 81.18%).

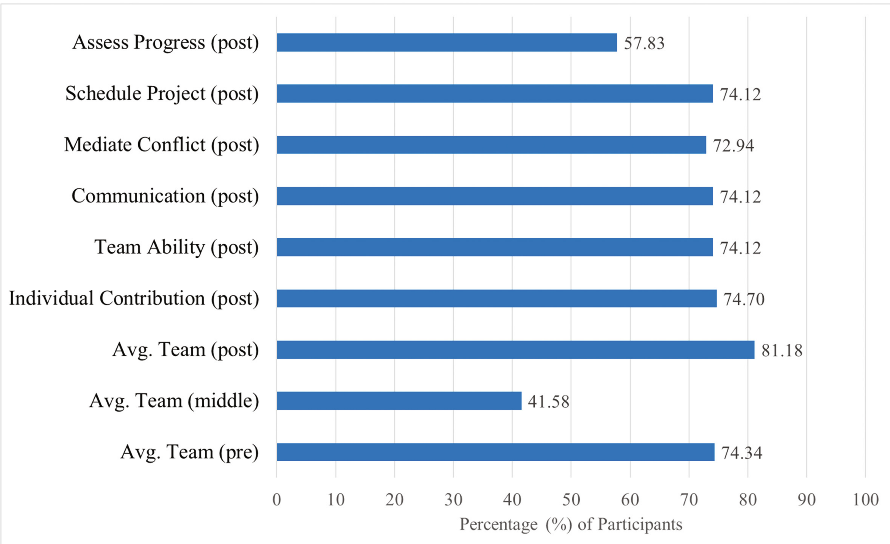

Fig. 3. Percentage of students assessing themselves higher than 3.5 (on a 1–5 scale with 5 being the most competent) for team competence pre, middle, and post, and the six core questions for team competence at the end of the course (post)

4 Conclusion

We have demonstrated that the combination of interdisciplinary project courses in the bachelor's and master's program of mechanical and process engineering at the Technische Universität Darmstadt leads to a gradual development of interdisciplinary competences.

An intensive advancement and testing phase for interdisciplinary project courses in all departments of the Technische Universität Darmstadt was developed by the university and funded by the national program "Quality Pact for Teaching". The result is a portfolio of five different types of interdisciplinary study projects that now can replace the existing monodisciplinary study projects. In most cases, interdisciplinary project courses are not introduced as a complete new module in a study program but as an equivalent for an existing project course module. This keeps administrative costs low compared to more than a year of redesign and reaccreditation that would be necessary for a completely integrated interdisciplinary study program.

With concern to the implementation, even for large project courses with up to 700 students, the additional efforts for the coordination of different disciplines amount to an average of six additional meetings of professors and/or scientific staff to elaborate the task design. During the project courses, the support of students is delegated to scientific and student tutors in order to relieve the professors. Thus, professors and external specialists can concentrate on expert advice.

Therefore, we see in this model a rewarding, effective and efficient way to incorporate interdisciplinary learning in engineering science curricula.

Next steps include the extension of, specifically, the interdisciplinary advanced design projects to the entire mechanical and process engineering department and other engineering science departments such as electrical engineering, civil engineering and computer science.

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Metacognitive Development in Engineering Students Through Cooperative Problem Based Learning (CPBL)

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Abstract. Metacognition is a skill set that has been identified to aid in the regulation of learning and problem solving. Constructivist learning approaches have been shown to be effective in enhancing engineering students' metacognitive skills development. One of the constructivist learning approaches is Cooperative Problem Based Learning (CPBL), which is the integration of principles of cooperative learning (CL) into problem based learning (PBL). The previous research shows strong evidence that the implementation of CPBL can help engineering students to develop metacognitive skills. The purpose of this research is to investigate engineering students' metacognitive skills development as they go through CPBL. An exploratory study approach was adapted in this research by conducting semi-structured interviews on three students. The data was analysed to get the complete picture of the students' metacognitive development.

Keywords: Metacognitive skills · Cooperative Problem Based Learning · Engineering education

1 Introduction

The 21st century is a challenging time for engineers from various aspects. Future engineers are required to have high competitiveness on the quality of knowledge and skills as globalization come across in all industry. Engineering education is also facing challenges in terms of integrating knowledge and practice in a way to prepare the students to enter the profession (McKenna et al. 2010). Engineering accrediting bodies (ABET 2014; Canadian Engineering Accreditation Board 2014; Engineering Accreditation Council 2012) have listed the skills required by future engineers and one of the skills is problem solving. In relation to problem solving skills, Hollingworth and McLoughlin (2005) have discussed metacognitive skills as a repertoire of learning strategies, capacities to manage one's own learning, and awareness of one's own knowledge and skills. In addition, metacognitive skills are identified as a set of skills that aid in the regulation of learning and problem solving (Mohd-Yusof et al. 2014; Jacobs 2010; Case et al. 2001).

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The importance of developing metacognitive skills among engineering students has been stated in various engineering education research globally (Lawanto 2010; Litzinger et al. 2010, Davdovitz and Rollnick 2003; Downing et al. 2009). Engineering curricula predominantly adopt traditional method in teaching and learning, where knowledge is transferred from the lecturers to the students. However, from the literature, researchers in engineering education have put a lot of effort in preparing students to integrate their knowledge and skills. For example, Lawanto (2010) exposed mechanical engineering students with ill-defined problems, Davidovitz and Rollnick (2003) explored the Competency Tripod model and flow diagrams as the resources for enabling students' metacognition in a chemistry laboratory, and Downing et al. (2009) conducted problem based learning in their study. These efforts are in line with the suggestion by Prince and Felder (2007), which mentioned that constructivist approaches are best implemented to achieve metacognition in learning.

Constructivist approach have been recommended in developing metacognitive skills. Among them are cooperative learning (CL) and problem based learning (PBL) (Dolmans and Schmidt 2006; Prince 2004; Woods 2012). CL provides effective team working platform where students support each member in learning and produce high quality works (Johnson et al. 2006; Felder and Brent 2007). CPBL on the other hand is the combination of CL and PBL (Mohd-Yusof et al. 2014).

The CPBL model facilitates the teaching and learning of a big group up to 60 students with one floating facilitator (Mohd-Yusof et al. 2016; Helmi et al. 2016; Mohd-Yusof et al. 2012). Similar to PBL, the CPBL model requires the problems to be realistic and ill-structured. The CPBL learning environment is underpinned by the principles of constructive alignment (Biggs 1996; Bigs and Tang 2010), How People Learn (HPL) framework (Bransford et al. 1999), PBL as the philosophy, and CL to develop learning team (Johnson et al. 2006). The implementation of CPBL is divided into three phases:

1. Phase 1 consists of problem restatement and identification.
2. Phase 2 consists of peer teaching (which includes individual peer teaching notes, team peer teaching, and overall class discussions), synthesis, and solution formulation.
3. Phase 3 consists of generalization, closure, and internalization.

Students have to write reflection journal in Phase 3. Reflection is an act of giving meaning to prior experience and determining how that meaning later guides future actions (Turns et al. 2014). Turns et al. (2014) suggested integrating reflection on experience as an intentional form of thinking. Reflecting on an experience also means using a specific lense to make meaning of the experience. They have also considered that reflection and metacognition are related to each other when the metacognitive concepts of self-awareness and self-assessment are highlighted.

Based on the highlighted issues and definitions, this research investigates how CPBL develops metacognitive skills when it is applied to a typical classroom setting. The research question for this study is "What are the metacognitive skills developed in each phase of CPBL?" The significance of this research is important to understand how metacognitive skills can positively impact students' learning. Since this study was conducted among first-year students taking an engineering course, the output of this study represents the entry level metacognition for engineering students.

The "Introduction to Engineering" (ITE) course is a three-credit hour course offered to first year chemical engineering students in a Malaysian university. The objective of the course is to bridge students' learning experience at school and learning to be an engineer in the university. Every semester students learn about engineering processes through problems with a theme in sustainable. In semester 1, year 2015/2016 session, the students were given a nine-week project about energy sustainability. Students were divided into teams of three or four across genders, races and academic achievements. The overall project to solve the problem was divided into three main stages as follows:

Stage 1: Familiarization of Sustainability and Benchmarking
Stage 2: Audit of Energy Consumption
Stage 3: Propose Engineering Solution and Economic Analysis

Details on the ITE course can be seen in Mohd-Yusof et al. (2016).

2 Metacognition

Metacognition is about taking ownership of one's learning and maximizing it. It is the knowledge and awareness of the process and the monitoring and control of such knowledge and process (Efklides 2001; Flavell et al. 1993; Schraw and Moshman 1995). The definitions of metacognition are the *compilation* of knowledge of one's own and others' cognitive processes; *planning* prior to performing a task; *monitoring* one's own thinking, learning and understanding while performing a task; *regulating* one's thinking by making the proper adjustments; *evaluating* one's own thinking by judging the progress and *controlling* thinking to optimize performance. There is a general agreement that metacognition can be divided into two general constructs, termed as metacognitive knowledge and metacognitive control and regulation which is also known as metacognitive skills (Kluwe 1982; Brown 1987; Pintrich et al. 2000). This study used the metacognition model by Pintrich et al. (2000). Metacognition model by Pintrich et al. (2000) consists of metacognitive knowledge, metacognitive judgment and monitoring, and self-regulation and control as listed in Table 1.

According to Pintrich (2002), metacognitive knowledge is defined as the knowledge individuals have about their own cognition and cognition in general. This is the knowledge about when, how, and why to engage in various cognitive activities (Baker 1991). The knowledge includes person, task, and strategy knowledge (Flavell 1979). It also involves self-awareness relying upon self-knowledge and self-appraisal through reflectivity (Zimmerman 1989). According to Flavell (1979), knowledge of person is the knowledge about self. Self-knowledge includes knowledge of one's strengths and weaknesses, knowledge on when one does not know something and having to rely on some general strategies for finding the appropriate information, and self-awareness (Pintrich et al. 2000). This knowledge is an important component in metacognition (Tarricone 2011). Pintrich et al. (2000) highlight that self-knowledge is essential for knowledge and belief about one's motivation which involve self-efficacy judgment, task goals, and the significance and importance of the task.

Table 1. Metacognition model based on Pintrich et al. (2000)

Metacognitive knowledge	Metacognitive judgment and monitoring	Self-regulation and control
1. **Knowledge of cognition and cognitive strategies-knowledge** about the universals of cognition a. Declarative knowledge on *what* different types of strategies are available for memory, thinking, problem- solving, etc. b. Procedural knowledge on *how* to use and enact different cognitive strategies c. Conditional knowledge of *when* and *why* to use different cognitive strategies 2. **Knowledge of tasks and contexts** and how they can influence cognition 3. **Knowledge of self-comparative** knowledge of intra-individual and inter-individual strengths and weakness as a learner or thinker; better seen as motivational not metacognitive self-knowledge	1. **Task difficulty or ease of learning judgments** (EOL)-making an assessment on how easy or difficult a learning task will be to perform 2. **Learning and comprehension monitoring or judgments of learning** (**JOL**)-monitoring comprehension of learning 3. **Feelings of knowing (FOK)-**having the experience or "awareness" of knowing something, but being unable to recall it completely 4. **Confidence judgment-making** a judgment on the correctness or appropriateness of the response	1. **Planning activities:** Setting goals for learning, time use, and performance 2. **Strategy selection and use:** Making a decision about which strategies to use for a task, or when to change strategies while performing a task 3. **Allocation of resources:** Control and regulation of time use, effort, the pace of learning and performance 4. **Volitional control**-control and regulation of motivation, emotion, and environment

Other components of metacognition are self-regulation and metacognitive judgment and monitoring (Pintrich et al. 2000). Self-regulation is a self-regulatory skill, in which an individual monitors his learning process (Zimmerman 1989). Pintrich (1989) asserted that metacognitive strategies can promote students' achievement when they are motivated to use them in regulating their cognition and effort. Important interactions between metacognition and self-regulation are control, monitoring and regulation of strategies to meet task demands and goals (Tarricone 2011). Self-regulated learners are highly motivated, goal orientated, committed, independent, and active (Zimmerman 1989; Wolters and Pintrich 2001). Self-regulated learners are also aware of their knowledge, belief, volition, focused, goal-oriented, and persistent in learning processes (Pintrich et al. 2000; Wolters and Pintrich 2001; Zimmerman 1989). On the other hand, personal expectations of achievements and attainments facilitate the development of self-regulation (Flavell 1979). Even though self-regulation is considered a separate process from metacognition, it might arise during the application of the metacognitive process.

From constructivist perspective, self-regulation and metacognition cannot be separated because metacognition covers self-regulation. Self-regulated learning in the model by Pintrich et al. (2000) is an active and constructive process where students set goals for their learning and attempt to monitor, regulate and control their cognition, motivation and behavior guided and constrained by their goals and the contextual features in the environment.

Metacognition and self-regulation have varied roots. Metacognition is cognitive orientation (Flavell 1979), while self-regulation is human action rather than the thinking that cause the action (Bandura 1977). However, those roots became increasingly entangled especially in academic domain (Zimmerman and Schunk 2001; Graham et al. 1991; Dinsmore et al. 2008). According to Dinsmore et al. (2008), the distinction between metacognition and self-regulation are the difference emphasize on the role of the environment. From the perspective of self-regulation, environment stimulates the individual awareness and their regulatory response. In contrast, from the perspective of metacognition, the focus is on the mind of the individuals as the initiator or trigger for subsequent judgment or evaluations.

3 Method

This preliminary research is an exploratory study to investigate how students develop metacognitive skills while undergoing CPBL. This research used semi-structured interviews suited to exploratory aims of the study. Open-ended questions were designed to explore the underlying themes of metacognition such as: “What your feeling when you encounter the problem?”; “What do you do during problem restatement and problem identification?”; “What happened during peer teaching?”; “How do you decide your final solution?” and “What do you feel after presentation and submission the report?”

Three students (Students A, B and C) from the first-year Chemical Engineering program that went through CPBL in the ITE course were chosen based on convenient sampling technique for the interview. The number of sample is sufficient since the study is for exploratory purposes. The interviews were conducted three times based on the three main stages in the energy sustainability project. This means that the researcher interviewed the students after the completion of each stage. Each session of interview consumed about 15 to 20 min. The interviews were conducted in both English and Malay languages, depending on the students’ preference. Then, the interviews were fully transcribed into interview transcripts.

To analyze the interview, a significant amount of time was spent in reading and developing coding to assist the analysis process. Thematic analysis technique by Braun and Clarke (2006) was used to analyze the data. The steps to perform thematic analysis are: to get familiarized with the data, to generate initial codes, to search for themes, to define and name the themes and to produce the report. The researchers familiarized themselves with the data by reading the transcript for several times while jotting down the possible initial coding. The coding was based on the objective of the research, “what are the metacognitive skills developed in each phase of CPBL?” based on Pintrich et al. (2000) metacognition model (Table 1).

The codes generated include knowledge of person, knowledge of task, knowledge of strategies, task difficulty of learning judgment, learning and comprehension monitoring, confident judgment, planning activities, strategy selection and use, and control and regulation of time. Later, all the codes were gathered together and arranged in a table. In the third phase, all the codes were gathered with the quotations to identify the emerging themes. The themes were reviewed in the fourth phase by checking the transcripts. In the fifth phase, names were given to the themes. The final phase was to produce the report.

4 Result and Discussion

Table 2 shows the themes and the related codes. The sample data with codes under the theme of "metacognitive knowledge", "metacognitive judgment and monitoring" and "self regulation and control" are listed in Tables 3, 4 and 5 respectively.

Table 2. Themes and related codes

Themes	Codes
Metacognitive knowledge	Knowledge of person
	Knowledge of task
	Knowledge of strategies
Metacognitive judgment and monitoring	Task difficulty of learning judgment
	Learning and comprehension monitoring
Self-regulation and control	Planning activities
	Strategy selection and use
	Control and regulation of time

Table 3. Examples of quotation for themes "Metacognitive Knowledge"

Codes	Students	Sample of quotation
Knowledge of person	B	The way I choose content to put in my peer teaching notes… I will take the points related to Stage 1. I will neglect the complex points. Because I think that was hard to understand
	A	That's true what the lecturer told us that our level of thinking is not too deep… During analysing I feel uncertain the way I analyze is true or not
Knowledge of task	A	I got the data by snapping the meter reader. I think everyone do the same thing
	B	I think there are many things that I can improve. For example, justification to choose the countries as the benchmark not only based on the population or the size of the country but also the pattern and style of energy consumption. So, many aspects can be considered

(*continued*)

Table 3. (*continued*)

Codes	Students	Sample of quotation
Knowledge of strategies	A	I feel demotivated when I start to understand, at the PR n PI stage, and the moment to get the learning issues. After that, I will refer back during peer teaching. Then, I will refer to the original PR and PI
	C	For Stage 1, after doing the peer teaching for almost 90%, I understand. I understand everything that is being delivered. It is because before that I search for the information on my own, I read and I don't know what I read. So, I just do notes in Microsoft words, then I prepare some questions for things that are unclear for me, because I couldn't imagine what the things it is?

Table 4. Examples of quotation for themes "Metacognitive Judgement and Monitoring"

Codes	Students	Sample of quotation
Task difficulty of learning judgment	C	But when we are being exposed to CPBL, we learn to do problem identification and problem statement. The hardest thing is to identify the problem identification. How we want to distinguish between what we need to know and learning issues
Learning and comprehension monitoring	B	Now, I feel ok, because I can see the details on how to do the data collection. At first I thought that we can use only 2, 3 methods, but after discussing in class with the lecturer there are 8 to 9 methods for data collection. I do the discussion with my teammates after the class. So we decide to take 4 methods, more than before

Phase 1 of CPBL consists of problem identification and problem restatement. Students were asked to meet the problem individually and do their own problem restatement and identification outside of class (Mohd-Yusof et al. 2011a). Then, in class, students discussed the problem restatement and identification with their teammates to reach a consensus, followed by overall class problem identification and analysis. The expectation from Phase 1 activities was students will be able to produce their own problem statement and to differentiate 'what we know', 'what we need to know', and come out with learning issues. According to Brown (1981), knowing what you know and do not know relies upon awareness and the checking of understanding, meanwhile knowing what you need to know involves knowing what type of knowledge and information is needed to meet the task demands.

The facets of metacognition that were developed in Phase 1 were metacognitive knowledge (knowledge of person and knowledge of strategies), metacognitive judgment (task difficulty of learning judgment) and self-regulation and control (planning activities). In stage 1, when the students encountered the problem, most of them agreed

Table 5. Examples of quotation for themes "Self-regulation and Control"

Codes	Students	Sample of quotation
Planning activities	C	For example, before this the questionnaire was planned to be distributed to male and female at L07 and L04 respectively, but the power meter was only located at L04. So we decided to distribute the questionnaires to L04 residents only. We found out that the cause for high consumption in L04 and compared it with power meter
Strategy selection and use	B	We had an argument in our group. When I look at Dr. Zaki's class they are doing benchmarking using other countries. They show the data from different countries for each learning issues. For example sustainable development, they show the countries for benchmarking and for sustainable energy, they put the countries for benchmarking. We realize that the students from our class didn't do like that. My team rediscuss; we brainstorm each possible solution and chose the best solution. We decided to tell what is "benchmarking", but all of us already know during peer teaching. So this time we decided to present the countries for benchmarking referring to the learning issues
Control and regulation of time	B	I will allocate 4 days a week to think about this subject. Each day I will spend an hour. Every day I will constantly think about this project and also try to focus the other 6 subjects that I take

that the problem given are difficult. In other words, the students were able to assess the difficulties level of a learning task. This facet fall under metacognitive judgment and monitoring. For example, the students responded:

> *When we are being exposed to CPBL, we learn to do problem identification and problem statement. The hardest thing is to identify the problem identification. How we want to distinguish between what we need to know and learning issues*. (Student C)

> *Stage 1 focuses on energy consumption, it is hard to find the data and discover the learning issues. I need to do a lot of reading, I read journals from Science Direct. Sometimes I wonder 'is it true?' and sometimes not.* (Student A)

Upon dealing with a problem individually, the students could identify which strategies need to be closely aligned to get a clear information for identifying the problem and problem restatement. Requiring learners to individually prepare and submit problem identification is to invoke construction of their own understanding before coming to the class (Mohd-Yusof et al. 2011a, b). Knowing the strategies involves the ability to identify the appropriate strategies which match the task and hasten task completion (Brown 1981).

The students can also identify their capabilities to encounter the problem. This is known as knowledge of person. Knowledge of person includes the knowledge of one's strengths and weaknesses, knowledge on when one does not know something and have to rely on some general strategies for finding the appropriate information and involve self-awareness (Pintrich 2002). Both of this facets fall under metacognitive knowledge. Some of students' responses are:

> *Stage 1 focuses on energy consumption, it is hard to find the data and looking for learning issues. I need to do a lot of reading, I read journals from Science Direct. Sometimes I have a feeling 'is it true?' and sometimes not.* (Student A)

> *From the problem itself, I don't know what are the things that we need to learn. That's the hard part to determine. Because we only know the learning issues after we discuss it together in class. But before that, if we didn't discuss it in class, we do not know what is the learning issues.* (Student C)

The effect of Phase 1 activities is the students were able to develop planning skill which is considered as one of self-regulation and control skills. Planning activities consist of setting goals for learning, time use, and performance. The following excerpt from Student A indicate this phenomenon:

> *It helps me sometimes. For example in the Static course, I will study first on how to do the problem given, because before this when I got a question I just 'boom' to solve the question. Now, I will refer to book while doing the problem.* (Student A)

In Phase 2, self-directed learning will take place to fill their knowledge gaps in peer teaching session, to synthesize and apply them to formulate the solution. The concept of peer teaching was implemented in this phase to make sure the student is able to learn the new knowledge correctly (Mohd-Yusof et al. 2011a, b). Each member in the group was asked to prepare peer-teaching notes for his or her teammates. Next, the peer-teaching class was conducted to solve the critical or misunderstanding concept. The information gathered by the students was shared and critically reviewed so that the suitable ones can be applied to solve the problem.

The facets of metacognition that were developed in Phase 2 are metacognitive knowledge (knowledge of person, knowledge of task, and knowledge of strategies), metacognitive judgement (learning and comprehension monitoring) and self-regulation and control (planning activities, strategy selection and use, and control and regulation of time use, effort, the pace of learning and performance).

Individual peer teaching stimulated the development of knowledge of person. Pintrich (2002) highlights that knowledge of person is essential for knowledge and belief about one's motivations which involve self-efficacy judgment, task goals, and the significance and importance of the task. Knowledge of task refers to knowledge of processes and actions or essentially knowing how (Schraw and Moshman 1995). Developed through experiences and application, knowledge of task can become implicit, automatic process or refined strategies (Schraw and Moshman 1995). Positive or negative self-concept as a problem solver, self-efficacy, and intrinsic motivation can affect strategy selection, application and transferability (Tarricone 2011). The example of the excerpts that indicates knowledge of task in Phase 2 are:

> *I got the data by snapping the meter. I think everyone does the same thing.* (Student A)

> *Stage 2 occur during mid sem. I optimize my mid-sem break. During the break, I just keep on thinking on how to record the data at home. So, I recorded the data at home using google*

spreadsheet. Everyone can update their work there. And everyone can check each other work. Every day I will allocate my time to fulfill the spreadsheet. Once the break ends, I focus recording the data on Friday, Saturday, Sunday, and Monday only. (Student A)

Knowledge of strategies involved identifying goals and sub-goals and selection of cognitive processes to use in their achievement. This can be portrayed in a response by Student C:

During the process of selecting the appropriate country as the benchmark, I ask my teammates what kind of countries that we need to choose? They said that I can choose randomly. So then I choose Brazil and Sweden. Because I like Brazil and Sweden. I don't know why? So I search information about both countries. My other teammate study about Switzerland, Italy and.. I forget the last one..we didn't plan this process properly. We should finalize what are the countries that we choose to do benchmarking. But we didn't do that. We finally decide to take Sweden, Denmark, and Switzerland because of their renewable energy is high and study it deeper. (Student C).

In overall peer-teaching class, the students were able to monitor their learning and comprehension of learning. The students were also able to construct their own knowledge by extracting the important information and concept (Mohd-Yusof et al. 2011a, b) This is a platform where all the misunderstanding and can be cleared out. They can explain their understanding, inquiring about what they do not fully understand and learning through questioning (Mohd-Yusof et al. 2011a). Student C shared his experience as below:

In overall peer teaching in class, we were being divided into few groups and each group were given a topic, sustainable energy, sustainable development and renewable energy. I learn from that session. I was involved in the sustainable energy group and I understand about the topic clearly after that. Other students from various teams also contribute idea about their understanding on sustainable development. So, I learn and understand more about sustainable energy. The other learning issues that I learn is benchmarking. I went to the group that was responsible on it. I listen to their explanation about benchmarking. So it deepens my understanding. (Student C)

Self-regulation and control were developed during synthesizing the problem and formulating the solution. This is the transition of knowledge into application. This process requires a lot of thinking from the students. İn synthesizing the problem, students dissected and thoroughly studied the problem with the objective to understand how the problem emerged and how it grew to its current proportion, then combining the information and understanding in order to form a coherent whole (Woods et al. 2000). In generating the solution, students made judgments based on internal criteria that are logically correct and free from errors. Table 5 represents the excerpts of self-regulation and control in Phase 2.

Phase 3 consists of the presentation, reflection, and closure. Students were asked to present their solution in terms of oral presentation and report. Students were also asked to write a reflection journal in the process of internalizing the new knowledge and skills acquired. The closure was conducted in overall discussion on materials and skills learned (Mohd-Yusof et al. 2011a, b). In Phase 3, the students have the opportunity to improvise their metacognitive knowledge. This phase provided the platform for the students to look back and evaluate their understanding of their knowledge of person, task, and strategies. The reflection journals and the feedback from the facilitator are powerful tools where the metacognitive concepts of self-awareness and self-assessment are being highlighted (Turns et al. 2014). The example of excerpts that highlight knowledge of person, task, and strategies are:

> *That's true what the lecturer told us that our level of thinking is not too deep, during the analysis, I feel doubt that the way we analyze is true or not.* (Student A)

> *I think there are many things that I can improve. For example, justification to choose the countries to be benchmarked not only based on the population but also the size of the country and the pattern and style of energy consumption. So, many aspects can be considered.* (Student B)

> *The lesson I get after stage 1, we didn't hold a discussion early to identify the benchmarking. Oh..not discussion.. we didn't plan early actually. We need to plan what we are going to do. Our mistake is we didn't plan 100%. Only 50% and the rest we do the work for the sake of assignment. For the next stage, we should list down what we are going to do during the planning session, if there are misunderstood, just clear it out immediately by asking for somebody that know it.* (Student C)

In addition, students were able to develop their planning skills during the presentation. The time given for the presentation was seven minutes. In a short time, they are needed to present their solution. Student C admitted it from this following excerpt:

> *My group chooses Sweden, Switzerland, and Denmark. And now in our presentation, we want to deliver to the class what these countries have done. That the things we want to present. So each learning issues, we put the suitable countries as benchmarking. Then one of our team-mates suggests, for each of the benchmarks, we allocate 20 seconds during the presentation.* (Student C)

5 Conclusion

According to Downing et al. (2007), metacognition must be first developed before it can be used as a series of consciously controlled strategies. Downing et al. (2009) also prove in a quantitative study that PBL have a significant impact on the development of metacognition. In this research, it can be concluded that CPBL is an approach that definitely provides greater opportunity for the development of metacognition. However, a quantitative study should be conducted to see whether the students differ in their metacognitive development. The metacognitive development in each phase can be summarized as:

1. Phase 1: metacognitive knowledge (knowledge of person and knowledge of strategies) metacognitive judgement (task difficulty of learning judgment) and self-regulation and control (planning activities)
2. Phase 2: metacognitive knowledge (knowledge of person, knowledge of task, and knowledge of strategies), metacognitive judgement (learning and comprehension monitoring) and self-regulation and control (planning activities, strategy selection and use, and control and regulation of time use, effort, the pace of learning and performance)
3. Phase 3: metacognitive knowledge (knowledge of person, knowledge of task, and knowledge of strategies), self-regulation and control (planning activities)

Metacognitive development can be achieved if the students are willing to participate in activities in each phase. One of the crucial questions that should be asked for further study is, *'to what degree does metacognition help students to develop their problem solving skills?* Nevertheless, this exploratory study shows that the scaffolding provided in each phase of CPBL are able to develop metacognitive skills among students in a typical class setting. Further study shall be focusing to improve the effectiveness of CPBL in metacognitive development.

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Program Outcomes and Institutions Management Frameworks as Seen by EUR-ACE and by CTI: A Comparison of Criteria

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Abstract. In Europe, the European Network for Accreditation of Engineering Education (ENAEE) has created in 2005 a specific frame concerning different levels of accreditation of engineering education: the EUR-ACE label. This frame is now extending to other continents such as Asia and Africa. The agencies authorized by ENAEE to deliver EUR-ACE label have, amongst other points, to prove that they assess that the HEIs that they are accrediting satisfy criteria concerning their management and the learning outcomes of their graduates. This paper presents the reasons why Commission des Titres d'Ingénieur (CTI) - which is the French accreditation agency for engineering education - knows when it evaluates an institution that the requirements of the two accreditation systems are coherent.

Keywords: EUR-ACE · CTI · Learning outcomes · Program management · Engineering education

1 Introduction

In France Engineering education exists only at Master's level and CTI defined the learning outcomes that must be those of an engineer at this level. It also gives criteria concerning the management of the institution delivering its diploma, even if CTI's accreditation concerns programs.

However this framework changes every 3 or 4 years because society and engineers are changing: this change is also something mandatory because of ENQA. ENQA (European Network for Quality Assurance) is an institution that has defined rules (the European Standards and Guidelines) for agencies and recognizes the accreditation agencies that meet a good standard of quality in Europe.

Amongst those rules, the fact that agencies have to consult their stakeholders before defining their criteria for accreditation, is a very important one and CTI follows this requirement it each time it changes its own accreditation criteria.

In February 2016, 14 key competences were considered as necessary for the graduates of the French engineering HEIs; this was voted as well by CTI members that are academic people as by members coming from industry - CTI is a joint agency

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between academy and profession, CTI was at the same moment reauthorized to deliver EUR-ACE label.

In 2015 ENAEE has had a strong debate about the evolution of its own criteria, the EAFGS [1]. We want to show how CTI's criteria [2] fulfill these new requirements.

Currently, ENAEE is also working with IEA, they already defined Best Practices and now they are comparing their criteria [3]. So, the work we present is of some importance because CTI, at this moment, has common discussions and reflections with ABET too. The possibility to know the specificities that make criteria common or different for each system is something fundamental for institutions to increase mobility of all students in the future.

2 Views of Both Agencies on Accreditation

2.1 Common Demarche

When ENAEE authorizes an agency to award EUR-ACE label, its first demarche is to observe twice the process that the agency uses to evaluate institutions: not only the reference books describing accreditation criteria are studied, but their real application during audits is also observed.

EAFGS includes three levels of recommendations for the institutions being evaluated:

- The first one concerns the working load of students The workload requirements are described using ECTS credits, in the EUR ACE system, Bachelor Degree programs are of a minimum of 180 ECTS credits while Master Degree programs represents a minimum of 90 ECTS credits which means that Master Degree programs which are integrated and do not include the award of a Bachelor Degree (the case of France) should include a minimum of 270 ECTS credits. As CTI specifies the necessity to give at least 60 credits for each of the five years of the engineering program, both requirements are coherent.
- The second one concerns the management of the institution delivering the program, we will present it in part 3.
- The third one concerns learning outcomes. Program Outcomes describe the knowledge, understanding, skills and abilities which an accredited engineering degree program must enable a graduate to demonstrate. These Program Outcomes have to be considered as the 'minimum threshold' and to be fulfilled in order to ensure the quality of engineering programs. The Program Outcomes can be used in both the design (by engineering academics) and the evaluation (by accreditation agencies such as CTI) of programs in all branches of engineering and for different profiles. We will compare CTI and EUR ACE requirements in part 5.

2.2 Objectives of Both Agencies

Both ENAEE and CTI are rooted in the so-called Bologna process which aims at building a European Higher Education Area by fostering student mobility and employability.

Their aims are the same with different geographic spreads: but very often when a French school is awarded accreditation, at the same time, it asks EUR ACE label.

This paper will compare the views on program outcomes and program management of the two agencies but it is important to signal that all requirements are compliant both:

- with the overarching framework of qualifications of the European Higher Education AREA (EHEA Framework of QF-EHEA) as adopted by the Ministers of Education of the Bologna Process at their meeting in Bergen in May 2005, including Dublin Descriptors [4]
- with the European Qualification Framework for Lifelong Learning (EQF) [5] as developed by the European Commission and signed on April 2008 by the Presidents of the European Parliament and of the council of the European Union.

Compatibility with a lot of different systems is something rather difficult to get but it is necessary because EUR-ACE extended to Russia some years ago and to countries of Central Europe last year, but also because projects are also launched with Maghreb and South America.

3 Program Management Requirements

The Program Management and Learning Outcomes requirements of CTI must be consistent with the Standards and Guidelines for Quality Assurance in the European Higher Education Area revised in 2015 (ESG) [6]. In the case of ENAEE, program management is compliant too but we must say that learning outcomes are only substantially compliant.

3.1 EUR-ACE Requirements for Institution's Management

Accreditation agencies should confirm that engineering degree programs, for which a HEI seeks accreditation are managed in a way that:

- The aims of accredited programs (1) reflect the needs of employers and other stakeholders. The program outcomes must be demonstrably consistent with its aims.
- The teaching and learning process (2) must enable engineering graduates to demonstrate the knowledge, understanding, skills and abilities specified by the program outcomes. The program curriculum must specify how this is to be achieved.
- The resources (3) to deliver the program must be sufficient enough to enable the students to demonstrate the knowledge, understanding, skills and abilities specified in the program outcomes.
- The criteria for student's admission (4), transfer, progression and graduation must be clearly specified and published, and the results monitored.
- Accredited engineering degree programs must be supported by effective quality assurance policies (5) and procedures.

So if an institution is awarded of Label EUR ACE through an agency, it must manage its program to achieve the program aims, it must provide a teaching and learning process that enables students to demonstrate achievement of Program Outcomes and for such the institution must provide adequate resources.

It must also monitor the rules for student admission, transfer, progression and graduation and comply with internal quality assurance procedures.

3.2 CTI Requirements on Management

As each quality agency dealing with programs, CTI does not only verify the content of the program, this is especially true because, in France there are not two kinds of accreditation for engineering education: institutional and programs ones.

So, when CTI accredits an institution, both the management of institution and programs are observed because this is needed to be confident on the future good realization of the program.

The surrounding of the curriculum, particularly the institution's partnerships, are also verified so as to be sure that the institution can really put in place what is expected; this means:

- the good organization (A) of HEI that includes both its mission, its governance, its communication and resources
- the partnerships (B) of the HEI convenient for the program
- the good organization of the program (C)
- the recruitment (D) of students correctly done
- the employment (E) of graduates is effective
- the quality assurance system (F) of the institution works well

Some of those criteria correspond to what ENAEE calls management, we will now describe them more in detail.

A The first item concerns strategy and organization of the HEI, it includes:

- The presentation of the HEI's strategy and identity A1
  The institution must have a real identity and a visible implantation: its statutes must guarantee an organization allowing the realization of its mission in good conditions. A document concerning strategic organization must have been realized in coherence with the global system in which the institution is included; this document must concern as well the evolution of the institution inside its surrounding, its international policy, innovation, sustainable development and entrepreneurship. Measures concerning diversity must be part of this policy.
  The institution must be able to show its real autonomy.
- A global view on education programs A2
  The institution must prove that it has had a reflection on its programs. Concerning engineer's education, its offer must be coherent with existing other education programs on the same site and in the whole region.

The institution must also develop continuing education to satisfy the needs of companies. It has a mission of knowledge broadcasting on engineering particularly towards high schools.

- The HEI's organization and management A3
  They must be fit for engineering education. This means that the different councils guarantee the representation of internal and external stakeholders.
  The dean must be clearly identified and he must be responsible in front of the administration council. The organization must allow the realization of the global policy in good conditions with transparent and efficient management process and an information system allowing a shared knowledge on information must be in place.
- Communication and image of the institution A4
  The institution is attractive and has elaborated a specific communication linked to its pedagogic project. Information on expected learning outcomes, recruitment and evaluation must be publicly available.
- Resources of the institution A5
  The institution has enough human resources to ensure its pedagogical project. Its infrastructures and financial means allow the accomplishment of its pedagogic mission.

B The second item concerns the partnerships of the HEI:

- Links with companies B1
  The institution has integrated its surrounding's waits: companies must be represented in the councils but also intervene in the curricula.
- Link with research and innovation B2
  The link between research and education must really exist: the research conducted by the professors must have some benefits for the students, it contributes to the quality of education and to the spirit of innovation; transfer activities must encourage the mind of teachers and students to entrepreneurship activities.
- International activities B3
  The strategy of the institution is presented, and particularly the elements which have importance for the development of internationalization of studies: double diploma, mobility of students and teachers.
- National networking B4
  The national recognition of the institution is important as well for the employment of students as for the resources coming from outside.
- Local actions B5
  The institution must contribute to regional projects development and site policy with socioeconomic community.

C The third item concerns education itself:

In those chapters the learning outcomes of programs are also described (in C3 and C4) but we will not present them now.

- The general architecture of curricula (C1) must be coherent with French recommendations.

- The manner in which the education project is designed (C2) and followed up and especially the way in which the needs of economy are taken into account during the program design must be presented.
- Pedagogic methods (C5) and the necessary equilibrium between all forms of pedagogies especially the necessity of practical teaching that we will also find in outcomes; we can also find description of elements concerning student life.
- Evaluation of results of students (C6) and attribution of the title of engineer, Bologna process has to be followed.

D Recruitment of students:

- The strategy of recruitment (D1) must be fitted for it.
- Organization and information about recruitment are publicized (D2).
- Ask that recruitment criteria be fitted to the strategy (D3 and D4) concerning expected learning outcomes, to verify that it is possible that the education succeed with the available students.
- Welcoming students (D5) in the school is realized.
- Diversity of recruitments (D6): this means that the institution has to guarantee social and gender diversity but also geographic one.

E The fifth item concerns employment of graduates:

- The analysis of jobs (E1 and E3) occupied by the graduates and prospective studies concerning employment that the institution have to be realized.
- The courses (E2) must be put in place to prepare students to look for a job.
- The strategy of long life learning (E4) dedicated to the graduates must exist.

F The last one concerns management of quality:

- Continuous improvement in all its dimensions is important: it is the point where institutions show how they have followed up the previous recommendations of CTI.

4 Outcomes Requirements

4.1 View of ENAEE

The standards describe the Program Outcomes that accredited programs must meet, but do not prescribe how they are realized. Consequently, no restriction is implied or intended by the EAFSG in the design of programs to meet the specified Program Outcomes. HEIs retain the freedom to formulate programs with an individual emphasis and character, including new and innovative programs, and to prescribe conditions for admission into each program.

As established by “The recommendations of the European Parliament and of the Council” of 23 April 2008, the descriptors for the first cycle in the framework of Bologna process correspond to the learning outcomes for the EQF level 6 and the descriptors for the second cycle correspond to the learning outcomes for the EQF level 7.

The Program Outcomes are described separately for both Bachelor and Master Degree programs with reference to the following eight learning areas:

Knowledge and Understanding:

In depth knowledge and understanding of mathematics and sciences underlying their engineering specialization
In depth knowledge and understanding of their engineering disciplines
Critical awareness of their specialization
Awareness of multidisciplinary context of engineering

Engineering Analysis:

Ability to analyze new and complex engineering products, processes and systems
Ability to conceptualize engineering products, processes and systems
Ability to identify formulate and solve unfamiliar engineering problems
Ability to identify formulate and solve complex problems

Engineering Design:

Ability to develop, design new and complex products
Ability to design using knowledge and understanding in their engineering specialization

Investigations:

Ability to identify, locate and obtain required data
Ability to conduct searches of literature and critically use databases
Ability to consult and apply codes of practice and safety regulations
Practical skills to design and conduct experimental investigations
Ability to imagine application of emerging technologies in their field

Engineering Practice:

Understanding of techniques and methods of analysis
Practical skills including use of computer tools
Comprehensive understanding of applicable materials equipment and tools and of their limitation
Ability to apply norms
Knowledge and understanding of the non-technical implication of engineering practice
Critical awareness of economic organizational and managerial issues

Making Judgments:

Ability to integrate knowledge and handle complexity
Ability to manage complex activities or project taking responsibility for decision making

Communication and Team-Working:

Ability to use adequate methods to communicate with specific publics
Ability to function effectively in national and international contexts

Lifelong Learning:

Ability to engage in LLL
Autonomy to undertake further study

We see that it is inside the detailed items (guidelines) composing a criterion that we must carefully look to be sure of the content of those criteria in front of those of CTI.

4.2 CTI Criteria Concerning Learning Outcomes

Concerning learning outcomes themselves, in CTI criteria reference book, their ordering is different from the EUR-ACE ordering and at the first glance, they seem not to be very coherent with the previous ones: they are ordered in 3 different chapters.

The six first criteria concern the acquisition of technical and scientific knowledge and the mastery of their implementation:

1. The knowledge and understanding of a large field of fundamental knowledge and the analysis and synthesis skills associated
2. The ability to mobilize resources of a specific scientific and technical field
3. The mastery of tools and methods of engineers: identification, modelling, and problem solving, even if those are incompletely defined or unfamiliar, the use of computer based tools, analysis and design of systems
4. The capacity to design, make concrete, test and validate solutions, methods, innovative products, systems and services
5. The capacity to lead researches as well fundamental as applied, to implement experimental devices, to be open to collaborative practices for work
6. The ability to find pertinent information, to evaluate its quality and to use it

The second chapter concerns the adaptation of graduates to the constraints of companies and society:

7. The ability to take into account the issues of the companies
8. The ability to take into account the issues of relations at work, ethics, responsibility, safety and health at work
9. The ability to take into account environmental issues
10. The ability to take into account issues and needs of society

Finally, the third chapter takes into account the organizational, personal and cultural dimension

11. The ability to insert in professional life, to integrate in an organization,
12. The ability to undertake and innovate either in the frame of personal and professional experiences

13. The ability to work in an international context
14. The ability to be self-aware, to make self-assessment, to manage skills.

5 Comparison of Those Two Sets of Criteria

It is sometimes a bit difficult to realize a good comparison on program management because EUR ACE let more freedom to institutions to organize themselves than CTI, it is the reason why we will only show that the requirements of EUR ACE are satisfied in CTI's one.

Concerning the learning outcomes, it is a bit easier though sometimes tricky because of the imbrication of items.

5.1 About Program Management

Many elements in CTI's criteria can appear as specific to French institutions, however some of the criteria are quite useful and even necessary so that the institution succeeds in giving the expected learning outcomes (specified in part 4) to its graduates.

It is on quality matters that things are clearer, CTI has progressed very much on this field thanks to ESG.

EUR-ACE criterion	CTI correspondent criteria
Aims of the program/needs of stakeholders	C1 and B2
Teaching and learning process leads to learning outcomes	C5
Sufficient resources	A5
Criteria for student's admission are clear	A4, D2
Quality assurance policy and procedures	F

General criterion on governance do not appear in EUR ACE, as well as international mobility or research preoccupations. The reason is that EUR ACE must fit to very different kind of organizations in many different educational systems.

5.2 About Learning Outcomes

We present item by item how criteria match to one another even if a strict comparison is not always the good solution but in this way we can be sure of the compatibility of the two sets of criteria.

Practically as the institution has defined its own criteria we assess that they are coherent with those of CTI and by transitivity we obtain the compatibility with EUR-ACE.

EUR-ACE criterion	CTI correspondent criteria
Knowledge and understanding	İn criteria 1 an 2, we find the knowledge: as well in basic knowledge as well as in the specific field of engineering concerned by the program
Engineering analysis	İn 1 and 3, we find elements corresponding to the ability to analyse a specific engineering problem
Engineering design	In 3 and 4 are the elements concerning as well the design of systems as well as the design of solutions, methods, products and services
Investigations	The criteria 5 is exactly what concerns applied or fundamental research
Engineering Practice	Criteria 4 includes the ability to test and valid the solutions previously designed, but we can also find here what corresponds to criteria 7
Making Judgements	Criteria 6 includes the capacity to be able to know if an information is pertinent and truthful
Communication and team working	Criteria 11 completely covers this field
Lifelong learning	Criteria 14 concern the management of one's knowledge that leads to lifelong learning

We discover that some of the CTI's criteria cannot be found in the EUR-ACE system. Some explanation must be made:

– Concerning the international aspect (criteria 13), which is very important for French people, some other European country do not consider it, or as in ABET system have specific diploma dealing with international affairs. It is only in communication that international is quoted and do not include in a mandatory way the necessity of mobility
– Entrepreneurship (criteria 12) is really something new that does not appear at this moment in the preoccupation of all countries but in EUR-ACE criteria concerning Engineering design, the design of new products and creativity linked with innovation is quoted and this can be the first step to entrepreneurship
– Criteria 8 to 10 concern sustainable development and tomorrow's society, we know that is a really politic point, and it is not evident for ENAEE that has to its criteria take into account the opinion of nearly all its members to make unanimity on, however, in the EUR-ACE criteria concerning engineering analysis we see that societal, health and safety, environmental constraints have be taken into account and in the criteria on investigation and engineering practice points concerning safety regulations are also quoted.

On the contrary EUR-ACE insists much more on complexity than CTI does in its criteria, it is because EUR-ACE has to cleary distinguish Bachelor and Master level.

But some other points appear in the documents of CTI which are not at all in the EUR ACE criteria such as new pedagogies, internships, international mobility; this correspond to the fact that ENAEE does not want to indicate one unique way to reach the goals it expects.

6 Conclusion

We do not present in this paper the Standards and Guidelines dedicated to the accreditation agencies, it is a complementary set with respect to the criteria concerning HEIs. They evaluate the effectiveness of the agency accreditation procedures in the evaluation of the learning process of the degree program and its compliance with the three chapters presented before.

As mentioned before, ENAEE has elaborated a rather general set of criteria specific for engineering, CTI is coherent with those criteria. An observation of CTI criteria with regards to the CDIO system would also be of interest to compare those two systems and so, to be able to know what are the lacks and differences.

All those points are very important for the mobility of students and graduates, and for their future, an institution that wants to put in place a partnership with another one should be aware of these different labels and verify that the potential partner has got them.

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Academia-Hospital Course Co-development: Developing an Internet-of-Things-Based Design Course for Engineering Undergraduate Students

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Abstract. Structured courses to teach emerging technologies have emerged to keep up with the advancement of the technologies. The creation of such courses is done within universities with very little, if any, involvement of external partners who are direct stakeholders. This chapter describes the co-development by academia and hospital of a design course for engineering undergraduate students to teach the concepts and skills of designing the emerging technology of Internet of Things, with real application in a hospital's emergency medicine department. Course co-development uses the frameworks of problem-based learning, technological pedagogical content knowledge, and industry collaboration. Using surveys and interviews of students, faculty staff, and hospital partners, course co-development is shown to have increased students' interest in the subject and students' learning of the subject, while at the same time it has provided hospital partners with a fresh perspective of their own practices.

Keywords: Course co-development · Internet of Things · Engineering undergraduate · Hospital

1 Introduction

Smart society has emerged around us and is in need of competent engineers with relevant expertise in emerging technologies. One of the emerging technologies is the Internet-of-Things (IoT), enabled by, among others, radio frequency identification (RFID), wireless sensor network (WSN), and smart mobile technologies. IoT has been applied in various applications including healthcare [1] and smart city [2].

While the technology to support smart society has developed very rapidly, structured courses to teach relevant concepts and skills have only recently been developed [3]. These are done in-house, i.e. within university, with no or very little involvement of external partners who are direct stakeholders. This is a missed-opportunity, both in fostering innovation through multidisciplinary collaboration [4] and in tapping the potential of problem-based learning (PBL) [5].

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PBL has been recognized as an enabler for meaningful and effective mode of the teaching of design course [6]. Real problems provide connection to the real world (the real-world element) as well as opportunity to contribute to the society (the service learning element). Those are two qualities that engender and sustain students' interest and motivation [7], as well as drive students' learning [8]. Collaboration with the external partners provides a means to bring in the real-world element and the service learning element into learning.

With the above motivation, the authors developed a design course for engineering undergraduate students centered on the theme of developing an IoT-based system with application in a hospital's emergency department. For clarity, the objectives were formulated as follows:

1. How might we develop a design course to teach the concepts and skills of emerging technologies of IoT, and
2. How might we develop a design course that brings in real-world element and service learning element

We address these two objectives through course co-development with hospital.

2 Frameworks, Theoretical Backgrounds, and Evaluation Methods

The design course has the following requirements and constraints:

1. The duration of the course is two semesters, equivalent to 26 weeks. This is according to the guideline in the university where this course was to be conducted. For implementation in other university where slight variation is expected, the duration may have slight influence on the workload of the students, but not the content of the course.
2. The audience is third year engineering students. Students may come from various engineering discipline, such as electronics, computing, mechanical, or biomedical engineering. Students fulfil design project requirement in their respective department by taking this course. Therefore, the modular credit of this course is equivalent to a design project.

Three frameworks were applied in co-developing the course as follows:

1. Problem-based learning (PBL) to design the project in a way that maximizes student's learning and experience
2. Technical pedagogical content knowledge (TPCK) framework to develop the course content and teaching materials
3. Industry collaboration framework to imbue the course with the real-world element and enhance the service learning element enabled by PBL.

2.1 Problem-Based Learning and Method for Evaluating Its Success

PBL is widely recognized as a successful approach to teaching and learning in practice-oriented areas of academic study, including engineering. It is a learning method grounded on the principles of using problems as a starting point for learning and then accomplished through projects [9].

The principles of PBL are concerned with the following roles: the role of teachers (as initiators and facilitators in the collaborative process of knowledge development), the role of fellow students (through peer-learning and in teamwork), and the role of problems (through the inclusion of real-life problems) [10] and generally follows the model of Kjaersdam [11] that brings together the following components: (1) Problem Analysis, (2) Problem Solving, and (3) Documentation, whose relationships is depicted in Fig. 1.

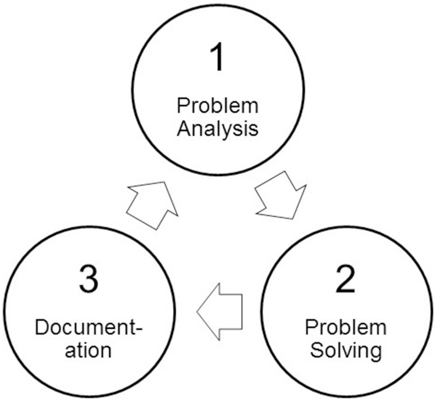

Fig. 1. PBL model

In the course that we developed, we followed the model of Kjaersdam [11], which will be elaborated in Sect. 3 as a case study.

It is worth noting that although PBL does not restrict problems to be real-life, our work in co-developing this course has been centered on real-life problems.

To evaluate the implementation of PBL approach in this course, we used a question in an anonymous student survey conducted at the end of the study. This method is adapted from a study by Ahlfeldt et al. [12]. Students were given the following statement in the survey "The course increases interest in the subject (applying IoT in real-life)", and were asked to rate their agreement to the statement using a 5-stage Likert scale. Additionally, students were also interviewed to collect more insights about their experience.

2.2 Course Co-development with Technological Pedagogical Content Knowledge and Method for Evaluating Its Success

The co-development of the design course was based on the framework of technological pedagogical content knowledge (TPCK) [13, 14]. This framework has the additional advantage of being able to drive the academia-industry collaboration.

The basis of TPCK is the understanding that teaching is a highly complex activity that draws on many kinds of knowledge [14]. TPCK starts as "two circles of knowledge" [15] known as pedagogical content knowledge (PCK), where one circle represents content knowledge and the other one represents pedagogical knowledge. PCK introduces the notion that content knowledge and pedagogical knowledge are not exclusive to each other, but that they intersect on which intersection PCK exists.

TPCK extends the PCK's circles of knowledge to also intersect yet another circle, i.e. technological knowledge. This reflects how technology has permeated classrooms and has changed the nature of classroom. It represents a class of knowledge that is central to teachers' work and that would not typically be held by non-teaching subject matter experts or by teachers who know little of that subject [16]. TPCK model is presented in Fig. 2.

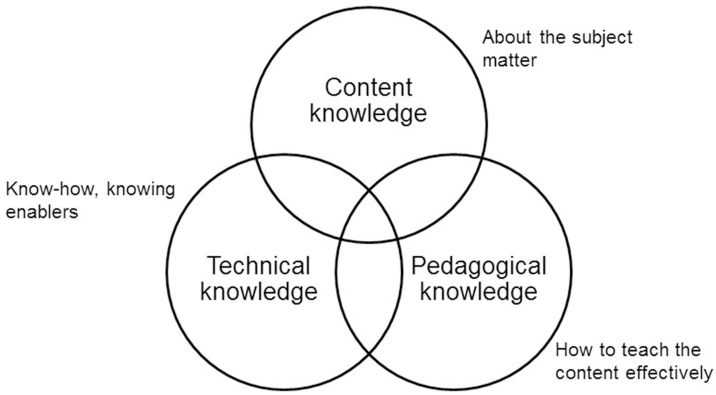

Fig. 2. TPCK model

In the course that we developed, we used the TPCK model to integrate the process of designing (the Content), the teaching and learning about design (the Pedagogy), and the IoT (the Technology).

To evaluate the implementation of TPCK in the design of the course, we used a question in an anonymous student survey conducted at the end of the study. This method is adapted from a study by Archambault et al. [17]. Students were given the following statement in the survey "The course enhances my thinking ability", and were asked to rate their agreement to the statement using a 5-stage Likert scare. Additionally, students were also interviewed to collect more insights about their experience.

2.3 Industry Collaboration Framework and Method for Evaluating Its Success

In the context of developing the design course, we used an industry collaboration framework with the understanding that “industry” in the framework is not limited to commercial or for-profit entities, but also applies to communities and organizations as long as they are outside of university. There is an international convergence of interest on issues about the purpose of universities and colleges and their role in a wider society that drives academia-industry collaboration [18].

There are many benefits to academia-industry collaboration, including access to university knowledge and insights into industry practice [19, 20]. Structured collaboration has been practiced in many universities, such as the University of Minnesota with its ten-point plan [21]. The strategy employed in those collaborations includes emphasis on the potential benefits of industry collaboration summarized as follows (depicted in Fig. 3):

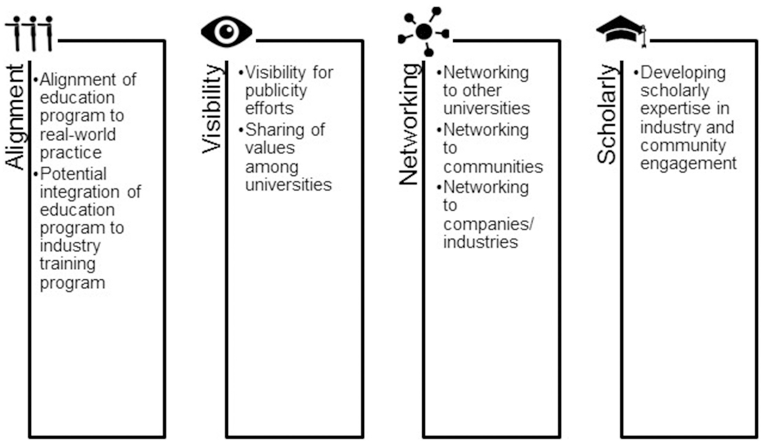

Fig. 3. Industry collaboration model

1. Alignment (of education program to real-world practice, and potential integration of education program to industry training programs)
2. Visibility (for publicity of efforts and sharing of values among universities)
3. Networking (to other universities, to communities, and to companies/industries)
4. Scholarly (in developing scholarly expertise in industry and community engagement)

While establishing and sustaining academia-industry collaboration has been well-practiced and well-researched, evaluating its success has not been well-explored. The problems with evaluating industry collaboration are as follows [22]:

1. A lack of focus on outcomes
2. A lack of defined and standardized instruments and tools

3. The variety of approaches currently being adopted

Efforts to measure the impact of industry collaboration has been done in various universities and invariably suffered from one or more of abovementioned problems. One would be able to draw lessons from efforts by University of Brighton [22], University of Bradford [23], University of Swinburne [24], and RMIT University [25].

Following the analysis of various tools of measuring community engagement [26], we follow the Campus Compact tool [27] as presented in Table 1 by adapting community engagement explained in the tool into industry collaboration.

Table 1. Campus Compact's tool of evaluating community engagement, adapted into evaluating collaboration with hospital as external partners [26].

Relevant for	Not relevant for
Measuring the impact of service-learning and hospital (or external partners) engagement initiatives on students, faculty, the institution, and the hospital	Understanding the micro-dynamics of engagement between individual university personnel, students, community groups, community members, and external partners
Providing a comparison of assessment methods, as well as sample assessment tools ranging from survey to interviews to syllabus analysis guides	Assessing research impact for the benefit of external partners

In this study, using Campus Compact's tool as a basis, hospital partners were interviewed to understand the impact of this program to the hospital.

3 Course Development: A Case Study

In this section, we will elaborate and present as a case study the development process, the course, and the evaluation of the course using the three frameworks described in Sect. 2, namely: (1) PBL, (2) TPCK, and (3) industry collaboration.

The course was developed by faculty members of the Innovation and Design-Centric Program (iDCP) [28, 29], National University of Singapore (NUS), with medical staff of the Department of Emergency Medicine (DEM) of Singapore General Hospital (SGH). The design course has been developed to align with the requirements of ABET for an engineering design course [30], where the course co-development with the industry was to imbue the course with real-world context. For the pilot implementation, 17 students were enrolled out of 65 students in the cohort.

3.1 Course Development Process

The problem/project of the design course was redesigning the processes and experiences in a hospital's Emergency Department (ED). The course planning stage involved faculty members/staff of university and doctors/staff of ED.

As the first step, university staff and hospital staff conducted a quick design process using the Design Thinking methodology [31], from which two broad design opportunities were identified for the course as follows:

1. How might we smoothen the information flow in ED?
2. How might we minimize non-medical work in ED?

These two design opportunities were selected considering: (1) that the scope of the problem/project was broad enough to stimulate student creativity to generate solutions, (2) that the potential solutions of these problems might include various disciplines in engineering and might also include emerging technology of the IoT, (3) that the goal of the projects can be re-articulated by engineering students without the need of having deep understanding of disciplines outside of engineering.

As the second step, university staff and hospital staff discussed the syllabus of the course. This pilot implementation was part of an established engineering design course, hence the core elements of design course, such as design methodology, was retained. The real-world context through ED fieldwork supplemented the literature reviews that students would otherwise be required to do to understand the problem. There was also design review co-conducted by ED users (e.g. doctors and nurses) that supplemented the design test stage.

As the third step, university staff then identified specific technical skills that students would require to accomplish the task, but were not yet possessed. Being third year engineering students, they would have acquired significant, but insufficient, technical skills to support an IoT-based project. Staff identified the required supplementary materials in consultation with syllabus/curriculum and teaching staff of various departments.

3.2 Course Description

The course run for 26 weeks. Students were grouped in team of 4–5 students. Students were required to submit team deliverables (carrying 70% of assessment) and individual deliverables (carrying 30% of assessment).

The course syllabus is presented in Table 2.

In Table 2, asterisk symbols (*) denote the sessions where hospital partners participate in the class.

3.3 Results and Feedback

At the end of the course, students were requested to provide a feedback using survey and interview as described in Sect. 2. Likewise, industry partners and faculty members were also interviewed.

Out of the 17 students, 9 returned their surveys and agreed for interview. The survey feedback from the students is presented in Table 3 in a 5-stage Likert scale, where 5 means “Agree”, 4 means “Somewhat Agree”, 3 means “Neutral”, 2 means “Somewhat Disagree”, and 1 means “Disagree”.

Table 2. Course syllabus.

Week	Topic	Deliverables
Week 1	Introduction to Module, Introduction to Design	
Week 2	Design Methodology: Systematic Approach in Design	
Week 3	Design Methodology: Innovation	
Week 4	Design Methodology: Engineering Design	
Week 5*	Project Work: Conducting Fieldworks in ED	
Week 6	IoT: Fundamentals in IoT	Project Clarification: Identifying and Formulating Problems
Week 7	IoT: Data Acquisition, Storage, and Management	
Week 8	IoT: Actuator Manipulation	
Week 9	IoT: Networks	
Week 10	Project Work: Design on Paper	
Week 11	Project Work: Design on Paper	
Week 12	Project Work: Design on Paper	
Week 13*	Project Presentation	Project Presentation and Proposal: Concept of Solutions and Project Plan
Week 14*	Project Work: Design Revision	
Week 15	Project Work: Prototyping	
Week 16	Project Work: Prototyping	
Week 17	Project Work: Prototyping	
Week 18	Project Work: Prototyping	
Week 19*	Project Work: Prototyping	Project Update
Week 20	Project Work: Prototyping	
Week 21	Project Work: Prototyping	
Week 22	Project Work: Prototyping	
Week 23	Project Work: Prototyping	
Week 24	Project Work: Prototyping	
Week 25	Presentation and Report Preparation	
Week 26*	Project Presentation	Project Presentation and Report

*Asterisk denotes the weeks where hospital partners came and taught the students.

Table 3. Feedback from student survey.

Question	5	4	3	2	1
Enhancing thinking ability	4 (44.44%)	4 (44.44%)	0 (0.00%)	0 (0.00%)	1 (11.11%)
Increase interest in the subject	3 (33.33%)	5 (55.56%)	1 (11.11%)	0 (0.00%)	0 (0.00%)

While the number of students surveyed is too small to make any statistically meaningful conclusions, we concluded the generally positive response of students towards the course.

From the interview, we identified two themes that emerged from this course as follows:

1. Motivation
2. Learning

Motivation. Motivation is defined as the forces that account for the arousal, selection, direction, and continuation of behavior [32].

Students were motivated to participate in the module because they perceived that they were truly a part of a team working in a real project. Furthermore, they perceived that they could apply elements of professionalism in the project. One student said: "The co-design environment has sped up my learning and made me realize how sharing of information can clear misconceptions in the design process efficiently."

Learning. Learning is a process whereby knowledge is created through the transformation of experience [33]. Experience plays a key role in the process [34], so much so that there is no meaning in a given situation until we relate our own experiences to it [35].

The real-world content of the course provided students with an avenue to learn from experience. Furthermore, it allowed students to learn and correct their erroneous perception of real-world – something that were valued by students.

As one student put it: "I had prior experience with ED, hence I came to the module thinking that I knew what went wrong and how to fix them. Now I realized that we cannot take assumptions for granted and should be open to change our understanding."

For the hospital partners, the co-development allowed them to generate potential solutions that would not have been thought of otherwise. As one of the hospital partners put it: "As I was listening to questions from students, many of which were not typical questions to me, I was forced to think differently and re-think many of even the standard practices in my own profession."

Another partner commented: "Healthcare workers, especially in a time-sensitive setting of acute care such as in an ED, tend to get so engrossed in their work that they often lose focus of the big picture. Instead of looking at the operations as one big interconnected system, they solely focus on the individual patient whom they are treating. While this is an admirable trait from patients' point of view, it gradually tends to make the system inefficient with many unproductive habits and practices built over time. The co-development process encourages objective questions and observations. Being unfamiliar with medical processes, students' questions were mainly from the point of view of resource optimization, thereby allowing exploration of solutions to improve processes in ED."

For the faculty members, the course co-development process has contributed to the scholarly development of pedagogy. As one faculty member put it: "The learning experience of the students is enhanced, and that makes a lot of difference in their motivation to learn, and to keep learning."

4 Conclusions

The course co-development that brings together academia and hospital could work well with the integration of PBL framework, TPCK framework, and industry collaboration practice. Such co-development could benefit students in their learning, hospital partners in their professional point of view, as well as academia in enhancing and improving pedagogical approach.

There remains to be seen how such course co-development can be done with different external partners, such as community centers, government agencies, industry, or start-up companies, who have very different objectives and concerns. Our future work includes working with other types of external partners and study the similarities and differences in course co-development.

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Motivating Engineering Students to Engage in Learning Computer Programming

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Abstract. Motivation is essential for successful engagement in learning. This factor is especially important in courses that are considered difficult and require high cognitive engagement such as computer programming. One of the approaches to motivate engineering students in learning is to create an effective learning environment. This paper presents a qualitative study on undergraduate engineering students' motivation towards learning programming based on the How People Learn (HPL) framework. The HPL framework comprises of elements that can be considered by instructors to design an effective learning environment. The methods designed for this study are observations and interviews while thematic analysis is employed in analysing the data. Findings based on lenses of the HPL framework are presented. Several recommendations for improving the learning environment are summarized as part of the outcomes of the study.

Keywords: Computer programming · Learning motivation · Learning environment · How people learn framework

1 Introduction

During the recent decades, there has been a tremendous development in numerical and computational methods for engineering tasks. Technical tasks in engineering are no longer always associated with manual calculation and estimation. Various computer programs and tools are developed for engineers to accommodate the needs of the 21st century towards high productivity and accuracy. Because computing is everywhere these days, there is a major need to have all engineering students to design and implement computing solutions.

Engineering Accreditation Council Malaysia (EAC) as one of the Washington Accord signatories, emphasizes on providing the students with the ability to use techniques, skills, and modern engineering tools necessary for engineering practice (Engineering Accreditation Council Malaysia 2012). This current need has drawn to the importance of equipping future engineers with computer literacy and programming.

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Hence, computer programming courses are compulsory in engineering curricular. Introductory computer programming courses, for example, are introduced as early as in the first semester of every engineering curriculum. These courses introduce students the basics of computer programming such as the use of computer and programs, related mathematical concepts, algorithm, and coding skills.

Poor understanding of basic programming concepts will make advanced computer applications courses more difficult. Courses such as numerical methods, control systems, process control, process simulation, artificial intelligence, and engineering design will need the students to at least understand on how to execute algorithms or coding using concepts of programming.

This study is conducted in an introductory programming course, offered by the faculty of chemical engineering to all first-year students, in a university in Malaysia. In the semester of the study, Semester 1 2015/2016, the course is taught by chemical engineering faculty members for the first time. Previously, this course is conducted and taught by the members of the faculty of computer science. The main aim of this study is to provide feedback to the faculty members involved so that the findings can be used to improve the implementation of the course. This is done in the spirit of continuous, evidence-based improvement in engineering education.

1.1 Motivational Issues in Computer Programming Courses

Programming is always associated with negative perceptions where students claim that learning to program is difficult and demotivating. The issue is engineering students are not motivated to learn programming due to its complexity (Heeg et al. 2014; Bowen 2004; Urban-Lurain and Weinshank 2001). Most programming languages are procedural and require a high level of abstraction, which is not easy for many students (White and Sivitanides 2002). It is also common that programming is perceived as difficult for novices of any age (Pears et al. 2007) with many adults have more difficulties with learning programming than children (Mladenović et al. 2016).

Among the motivational variables addressed by most researchers are self-efficacy, test anxiety, intrinsic and extrinsic motivation, and task value. Since motivation can be considered as the stimulus that causes the learner to take action or engage in the learning (Jerez et al. 2012), motivation can be predicted by their goals, efforts, readiness, persistence, and performance. Therefore, for most cases in learning computer programming, students with low motivation would prefer to adapt trial-and-error approach rather than learning the real problem-solving skills (Allan and Kolesar 1996). Students would also have the tendencies to give up and avoid to choose computer programming as part of their future projects (e.g. final year project) or career (Jenkins 2002).

Motivation also involves personal, social, and contextual variables (Schunk et al. 2014). One of the factors that may be more relevant in educational settings related to motivation is the learning environment (Bandura 1986; Chou and Hsiao 2011; Schunk et al. 2014; Svinicki 2004). Recent works dealt with the problem of student motivation in learning programming have agreed that the instructors should create an environment that can motivate the students (Gomes et al. 2012; Gomes and Mendes 2007a, b; Jenkins 2002; Jerez et al. 2012; Lister and Leaney 2003; Mendes et al. 2012;

Mladenović et al. 2016; Ring et al. 2007; Serrano-Cámara et al. 2014). This revolves around the learning strategies and teaching methodologies used (Jenkins 2002; Serrano-Cámara et al. 2014). Learning and teaching programming also often remains unchanged from the conventional teaching approach although the students and their learning environments are now significantly different (Mladenović et al. 2016). Moreover, if the introductory programming courses are generally labeled as overly difficult and hard to pursue, it will discourage the students from engaging in learning programming or enrolling other courses that require programming as the basic knowledge. Therefore, in the perspective of this study, to increase engineering students' motivation in learning programming, the learning will be scrutinized for future improvement.

To provide evidence-based recommendations, this study proposes to investigate the influence of the learning environment towards students' motivation in learning programming. Specifically, what can be done to the learning environment to motivate the students? In particular, this study focuses on answering three research questions:

1. What are the students' perceptions of the learning environment related to their motivation to learn?
2. What are the characteristics of the learning environment that influence the students' motivation in learning to program?
3. What are the recommendations to improve the learning environment?

1.2 Motivation and Learning Environment

This study is conducted based on two main concepts in education, namely, learners' motivation and learning environment. The conceptual framework is as described in Fig. 1.

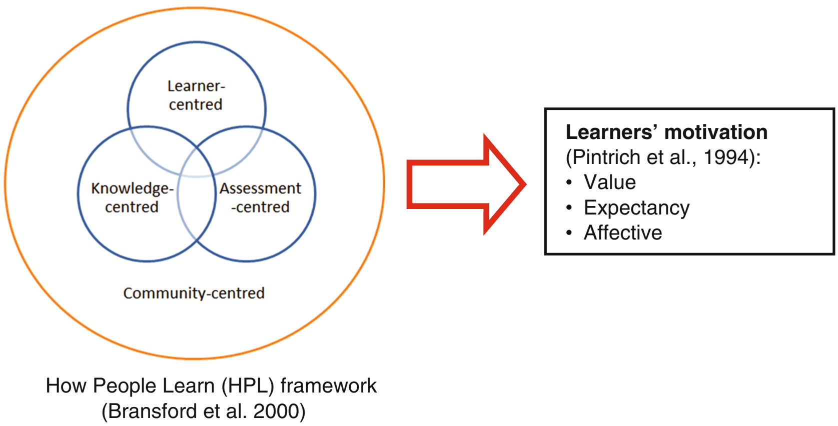

Fig. 1. Conceptual framework

Learners' motivation is a psychological factor that influences the students' engagement in learning (Pintrich et al. 1994). This study focuses on three concepts of motivational orientation which are the learners' value, expectancy and affective towards the learning environment (refer Table 1 for the definitions).

Table 1. Learners' motivation constructs based on Pintrich et al. (1994)

Motivation constructs	Description
Value	The learners' appreciation for a task. The degree of personal interest a learner has for a given task and includes beliefs about utility, relevance, and importance
Expectancy	The learners' belief about how they control their learning and the belief on their success rate in a task which is self-efficacy
Affective	The level of test anxiety among learners

Meanwhile, the characteristics of the learning environment are based on the descriptions of HPL framework (refer Table 2 for the descriptions). The HPL framework is a set of four overlapping lenses that can be used to analyze any learning situation.

Table 2. Descriptions of the HPL lenses (Bransford et al. 2000)

The HPL lenses	Description
Knowledge-centred	Concerns about the need to help the students become knowledgeable using teaching methods that lead to students' understanding and subsequent transfer Foster integrated understanding of a discipline e.g. pay attention to situations such as when students cannot relate the applicability of programming concepts to their major
Learner-centred	Includes understanding the students' characteristics, personal background, pre-conceptions, and beliefs e.g. consider the learners' need and ability as a part to develop interest and sustain their motivation towards using programming skills for engineering purposes
Assessment-centred	Emphasize on the importance of regulatory response in the classroom by which it means formative assessments are more often implemented compared to summative assessments e.g. students are able to receive feedback through formative assessment and from peers to help them determine their current performance and improve it
Community-centred	Value the community relationship among students and others around them, developing a sense of belonging and bond among them e.g. creates an environment that is safe to participate, ask questions, make mistakes and explore new things

2 Methodology

To answer the research questions, this study is conducted based on naturalistic inquiry research paradigm by Lincoln and Guba (1985) and Erlandson et al. (1993). Naturalistic inquiry research paradigm holds to the principles of where generalization is time and context bound and interpretation of a social situation depends much on the author as a researcher. Thus, the study must be set in natural settings and qualitative methods are preferred than quantitative methods with the notion of the human (researcher)-as-instrument.

The study started with classroom observations and followed by interviews. The observations were conducted for 14-weeks of lessons which are a whole semester. The studied course consisted of three different sections with the average of 30 students for each section. Therefore, for each week, the observations were done for the maximum nine hours (three hours for each section) and recorded in observation field notes.

At the end of the semester, a number of students were selected to be interviewed to get their perceptions about the learning environment and in-depth information about their motivation in learning programming. The reason for conducting the interviews at the end of the semester is to establish the reliability of the study providing that the respondents are very familiar with all of the class activities such as the lessons, tests, assignments, quizzes and mini project.

Purposive sampling method, as suggested by naturalistic inquiry approach (Lincoln and Guba 1985), was conducted to select the interview respondents which also enables the full scope of exploration. Hence, a sampling survey utilizing the motivation section of Motivated Strategies Learning Questionnaire (MSLQ) by Garcia and Pintrich (1996) was administered to the whole population prior to the selection. One part of MSLQ is designed to assess college students' motivational orientation in all learning contexts which fits the context of this study explained in Sect. 1.2.

Based on their scores, three to four students consist from the lowest, average and highest score groups were selected from each section to get the full scope of exploration. Ten students were interviewed. During the interviews, an interview guide was used as a guide and the interviewers were allowed to probe into new questions depending on the interviewees' response. The interviews were conducted for maximum one hour each and transcribed into interview transcripts for analysis.

Thematic analysis technique was employed on all observation field notes and interview transcripts. This method suits the nature of exploratory research of this study where the findings are in the forms of emerging themes. There are six phases in the thematic analysis based on the techniques by Braun and Clarke (2008). The interview transcripts were read at least three times each for data familiarization to produce the initial codings. Next, the codings were sorted into themes before producing the final report.

Meanwhile, in naturalistic inquiry approach, the terms reliability and validity is replaced by a term called as trustworthiness. To establish the trustworthiness of the findings, data triangulation is done by triangulating the observation and interview data. This method is one of the suggested methods to establish the trustworthiness of any qualitative study (Schostak 2002).

3 Findings

A demographic overview is done in the first week of observation to establish the context. The course ‘Introduction to Computer Programming’ consists of three sections with three different instructors. All of the sections are conducted at the same venue which is in a computer lab by given schedule. The students are provided with individual computer and space. The students also sat according to their preference at the beginning of the semester and some had changed places from time to time throughout the semester. From the observation, it was observed that all sections had practiced traditional teaching methods. Students used the computers to program using MATLAB while the instructors lectured using lecture slides. The instructors also used whiteboards to show some mathematical calculations and flowcharts as well as a front computer to show coding steps through a projector. The problems given in the course were individually planned by the instructor of each section. Therefore, the students in each section received different sets of problems depending on what was planned by their instructor. There were no significant changes observed in the teaching methods throughout the semester. The course assessment includes assignments for each week, two tests (for the first half and second half of the semester), and a final exam. Formative assessment was given orally. Very little formative assessment such as reflection journals or real-time feedback were observed.

From the data analysis, two themes emerged. The first theme is “knowledge-centred” where the codings are: “application”, “mini-project”, “relevance” and “credibility”. The second theme is “learner-centred” which includes the codings; “prior knowledge”, “learning culture” and “language”.

Table 3 summarizes the findings for theme “knowledge-centred”. For coding “application”, in the sense of creating a knowledge-centred environment, all of the sections have introduced adequate fundamental programming concepts in the learning materials. However, the connection and integration between the fundamentals of programming and the real-world engineering setting were minimally emphasized in all sections. The observation shows that the problems given were rather general. They were observed to be more focused on the generic mathematical calculation rather than trying to solve engineering related problems. Student C, for example, stated that,

> *“When I don’t understand, I feel demotivated. So, when I know more about the application of programming, I became more excited to learn about it.”*

The coding “project” refers to one of the assessments conducted in the course. Two out of three sections had included a mini project as part of the course assessment. As seen in Table 3, students who had the mini project mentioned that it was beneficial for them to develop their motivation to learn to program by relating it to the real application (Students D and C). On the contrary, students who were in the section without mini project felt that if they were given a mini-project, they will feel more motivated to learn to program (Student C and H).

In coding “relevance”, students stated that they did not put much effort for the course because they could not relate to the relevance of learning programming (Student E). Student J also mentions that by incorporating the relevance of learning

Table 3. Findings for theme "knowledge-centred"

Codings	Excerpts from observation field notes	Interview quotations
Application	The application of programming in engineering industry was minimally emphasized	When I don't understand, I feel demotivated. So, when I know more about the application of programming, I became more excited to learn about it. (Student C)
Project	Not all sections conducted the mini project	I had a friend who received a project assignment in her class, she told me about the application. When I understood the application, I became more motivated to learn. (Student C)
		The mini project… I think it was very helpful because I managed to learn so many things from it. Because we did it by ourselves, so we were really thinking, understood better because we did the codings many times. (Student D)
		I had a friend who received a project assignment in her class, she told me about the application. When I understood the application, I became more motivated to learn. (Student C)
		Some of my friends from other section had. I think it gave them some kind of experience in the programming more. Much more related to the real applications. You can start up with your own programs. That's what my friends did and it will make students more creative. (Student H)
Relevance	The relevance of programming was minimally emphasized	I just want to say that the students are not really putting much effort in this subject. They prefer to work hard on other subjects. I think because some of us cannot relate programming to chemical engineering, we saw no connection. (Student E)
		…increase motivation when teaching like tell about the advantages, like what are we going to do with that in the future. (Student J)

(*continued*)

Table 3. (*continued*)

Codings	Excerpts from observation field notes	Interview quotations
Credibility	Some students were more dependent on their peers rather than the instructor when the instructor was seen unsure about the topic/problem and inconsistent when explaining	His teaching was average but sometimes, he didn't even know about the question or topic that he taught. Same as well as us, we didn't know what to do. (Student B)
		Sometimes when we asked the lecturer, we don't feel confident to her because when we asked, she as well looked like she didn't understand it. (Student C)
		I don't think the lecturer has a lot of experience. I'm not saying that lecturer is not smart, but maybe if the lecturer explores more on the variations in MATLAB, she/he will understand what the students want. (Student E)

programming during the lessons, he will be more motivated. Moreover, based on the observation, the relevance of programming was minimally emphasized during the lessons.

For "credibility", it was observed that some students prefer to conduct discussion among them rather than consulting the instructors. This happened when the instructors hesitated about the topics of the day or inconsistent with their explanations. During the interviews, the students mentioned that instructors that are credible in the area of knowledge can help them to better understand what they learn and enhance their motivation to learn (Students B, C, and E).

Table 4 summarizes the findings for theme "learner-centred". For the coding "prior knowledge", it was observed that some of the instructors had concerns on this matter. A short survey was conducted by some of the instructors asking the students' previous knowledge in programming. Some students have been earlier exposed to computing and programming concepts during high schools and matriculation or foundation programs while some of the others have not. The students with prior knowledge in programming valued the learning more than the students without prior knowledge. This group of students was observed to know that programming requires deep-thinking learning skills and regulate their learning wisely. These students also asked the instructors and tried to explore programming regularly. On the other hand, students with no prior knowledge on programming tend to simply rely on the lessons, learning from the given materials and consulting their peers. During the interviews, some of the students mentioned that some students need consideration from instructors that they are new to programming (Students C, B, and E). For Student G, her confidence level to succeed the course were low because she was unfamiliar with programming.

Meanwhile, Student E, who has prior knowledge, observed that his friends who are without prior knowledge having difficulties to engage in learning.

For the "learning culture", to develop their motivation in learning computer programming, the students mentioned that they required more examples and exercise for the subject to satisfy their learning preference (Student D). A student also mentioned that he has his own learning approach which are trial-and-error (Student A).

In the coding "language", from the observation, one of the instructors sometimes chose to use the local language as the instructional medium instead of English. This finding is coded under the coding "language". The use of local language could be done since there was one section that only consists of local students. Even though this finding only emerged from the observation, the impact on the learning environment is significantly observed, appropriate for us to consider this as one of the codings. The students showed that the students were more responsive to the instruction when the instructor tried to re-explain some of the difficult parts of the lesson in Bahasa (the local language).

Table 4. Findings for theme "learner-centred"

Codings	Excerpts from observation field notes	Interview quotations
Prior knowledge	1. The existence of two groups of students; with prior knowledge and without prior knowledge 2. Students with prior knowledge portrayed actions showing that they are more engaged to learning, probed more questions, practiced regularly, and be explorative 3. Novice students waited for their more experienced friends to complete the tasks to get the answers and were always confused 4. The instructors' consideration of the students' different background and knowledge	In the class, not all of them have experience taking programming courses. He should take all of the students as zero level students. Because everything was not explained from the beginning, they were too sudden. Their motivation became low because they didn't understand. (Student B)
		I felt like I didn't want to learn it. It was like, I don't have any basics, but the lecturer taught as if everyone understands. (Student C)
		When there was the topic on multiplication, or/and, many didn't understand this topic. Because the students didn't understand that the output is in the binary, one or zero, not other numbers. The lecturer didn't fully explain that. Some students don't know even the basic of binary, so how to expect them to understand the more advanced topic. So the explanation should satisfy students with different experience. (Student E)

(*continued*)

Table 4. (*continued*)

Codings	Excerpts from observation field notes	Interview quotations
		I didn't expect to get an A for this course. If I am able to understand as many as I can, that's it. It is because I didn't have any basics in it. (Student G)
		I think they didn't put as much effort as on the other subjects. They put very much effort on the other subjects. I could not see their much effort on the programming course. Their reasons were mostly, "I was a Biology student previously", "we never learned about engineering", "we never learned about programming". I think it will be difficult since they are not used to it. (Student E)
Learning culture	–	For me, my learning styles are more on looking at the questions, try it and imagine the solution, then look at the given solution and later compare my own solution with the given solution. (Student D)
		I prefer to… try and error. (Student A)
Language	The instructor sometimes chose to use the local language as the instructional medium	

4 Discussion

As a preface to the discussion of the findings, a summary for quick reference to the three main themes is described in Table 5. The table shows the themes, the discussion from the perspectives of learning environment (HPL) and motivation, and the recommendations for improvement.

To develop a more knowledge-centred environment for the course, contextualization is helpful to develop students' value towards learning programming. From the knowledge-centred point of view, the students will be more motivated when they can see the relevance of learning programming and the applications (Bransford et al. 2002; Bransford et al. 2000). For this reason, the course content can be improvised by including more content and exercises from engineering contexts which set the overview of the application, relevance, and importance of programming in the students' future job. Meanwhile, providing the students a mini project related to their field will also increase the students' value on the real use of programming in their field.

In terms of the credibility of the instructors, it is important that the students can perceive the instructors as credible and reliable. In HPL, credibility is premised on the assumption that the instructor has a good foundation of the knowledge taught and is

Table 5. Summary of discussions and recommendations

Themes	Discussion		Recommendations
	Learning environment	Motivation	
Knowledge -centered	Contextualization: the emphasization on application and relevance of learning programming in engineering, and hands-on project as part of the assessment	Contextualization can help to develop students' value towards learning to program	1. To provide content that includes more engineering contexts 2. Design a course project consists of a real-world engineering problem (mini project)
	Credibility: the ability to become consistent in every teaching action and have adequate knowledge of the content	Uncertain or inconsistent actions during teaching affect the students' value on learning and expectancy to success	1. To have proper course plan (including the outcomes, activities, assessment and alignment of these three) 2. Instructors with ample knowledge on programming
Learner -centred	Students have their own pre-existing knowledge on programming	1. Students with prior knowledge in programming value the learning more compared to the students with no prior knowledge 2. Students without prior knowledge level of expectancy in learning 3. Students' value toward programming can increase by end of task satisfaction	1. To plan a cooperative learning environment to support both groups of students 2. To get the students' background information as a part of a diagnostic teaching 3. Learning materials, programming terms, and visualization of the concept that match the students' pre-existing knowledge 4. Begin the course with informal ideas that students have about their daily life and help them to transform the ideas to understanding programming 5. Provide questions and examples that consist of all degrees of difficulties to satisfy both groups of students

able to create transferable learning (Bransford et al. 2002; Bransford et al. 2000). Additionally, credibility is defined as the ability to become consistent in every teaching action (Bandura 2001). In this perspective, uncertainty and inconsistent actions during teaching can decrease the students' value and expectancy on what they are learning. To develop students' value on the task and increase their belief to succeed the course, it is important to have instructors who plan and are well-versed in programming.

In learner-centred perspective, students' prior knowledge is one of the most the important aspect to be considered. In this course, the students consist of those who have been previously introduced to programming and those who do not have any knowledge in programming. With the existence of these two groups of students, it is found that the novices are much more struggled to keep themselves motivated throughout the learning process. They can easily get frustrated and tend to give up during the learning process and believed their success rate is low. The differences in characteristics between these two groups of students also support the observational findings where the students with no prior knowledge depended on students with prior knowledge. This situation, however, cannot always be negatively viewed. These natural contributing factors are unavoidable in everyday life (Forte and Guzdial 2005). Concerning on the existence of these two groups of students, the instructors can plan a cooperative learning environment to promote impactful learning among students.

Also, to address this situation, the students' motivation can be improved by integrating the students' pre-existing knowledge to the course's instruction. This is one of the highlighted aspects towards creating a more learner-centred learning environment (Bransford et al. 2000). Moreover, if the concepts to be learned and the way they are organized match neatly with the pre-existing knowledge, then the learning is likely to be smooth and rapid (Gomes et al. 2012). Another approach to this situation is to provide learning materials that consist all degrees of difficulties to satisfy both groups of students. This is because experienced students would find it boring if the questions are too easy while the novice students would find difficult questions as frustrating (Bransford et al. 2000).

This issue also highlights the instructors' efforts to understand students' background information as part of the considerations while planning the course. Diagnostic teaching is a way for instructors to gain information from the students to improve their teaching such as observations, conversations, surveys and reflections (Bransford et al. 2000). The information will allow the instructors to think on the level of difficulties of the tasks, provide scaffolding to the students and provide opportunities for discussions.

The findings also show that the students are bound to their own learning culture or preference. This situation is unavoidable. In the context of this study, the students' dependency on examples and exercises is high due to their familiarity with the traditional learning environment. For such cases, changes in the students' conceptions are necessary (Bransford et al. 2000). This can be changed by (for example) beginning a course with informal ideas of what the students have about their daily life and help them to transform the ideas into understanding programming. It can improve their understanding rather than focus on examples and exercises. Another benefit of shifting from memorization and doing exercises to this type of learning is the students will have high satisfaction when the task is completed and thus will increase their value on the task.

For the use of local language as the instructional medium, it helps to connect the students' language with programming concepts. In the perspective of learner-centred, language practices can also provide basis for learning motivation by improving the students' preference during learning (Bransford et al. 2000).

5 Conclusion

Motivation in a major issue in many programming courses for engineering students around the world. The instructors may not easily change or influence the factors outside the classroom such as the institutional and community norms, the attitudes and beliefs of the students' surrounding people, or the students' family background and beliefs. On the other hand, the instructors will be able to change and control what they do in their own classrooms.

Mapping the findings emerged from the observation and interviews; it shows that learning environment does influence engineering students' motivation towards learning programming. This indicates that there is a need for making changes in programming courses' learning environment to motivate the students. It also provides some insights on the aspects that should be highly emphasized to create an effective learning environment. The ideas of understanding the student's pre-existing knowledge, learning culture and language can make a significant impact on the students' motivation and thus can develop better engagement. Additionally, the instructors' characteristics in terms of their credibility, planning, and consideration will also help to create a motivating learning environment. Meanwhile, the integration of the relevance of learning programming and its application in engineering would help the students to be more motivated to learn programming. Most importantly, these aspects should be properly integrated and aligned to best meet the outcomes of teaching programming to engineering students.

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The Power of Self-evaluation Based Cross-Sparring in Developing the Quality of Engineering Programmes

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Abstract. This paper discusses how the quality of engineering education can be improved in practice by using a process of sharing and critique. Starting with a self-evaluation followed by a cross-sparring with critical friends, this new approach has proven successful in initiating change. With a focus on quality enhancement as much as quality assurance, the engagement in and attractiveness of the engineering education are key considerations of the development activities that are inspired by the process. In the process programmes are paired with appropriate partners and, using the self-evaluation as a foundation, the cross-sparring enables each partner the best opportunities to learn from each other. The approach has been developed in an ERASMUS + project involving eight European universities and has been called QAEMP (Quality Assurance and Enhancement Market Place).

Keywords: Engineering programme development · Programme improvement · Self-evaluation · Cross-sparring · Quality enhancement · Quality assurance

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1 Introduction

In Higher Education today, institutions are constantly trying to balance the time spent and resource allocated to the areas of Quality Assurance (QA) and Quality Enhancement (QE). Often the quality assurance element dominates as this is what is most closely linked to the measures identified by institutions and accrediting authorities for ensuring a high level and consistent tertiary learning provision. In current times where university rankings are also of importance to many institutions, it is the quality assurance work that will be seen as driving improvement. Quality enhancement is often only identified in bespoke projects or it is left to the enthusiasm and energy of programme managers and individual teachers. This can be viewed as a missed opportunity as a robust embedding of quality enhancement will potentially have a greater impact on student learning, and any league table rankings that may be produced. In the European Union Erasmus + project described in this paper, the focus is on continuous improvement, a subject very familiar to engineering practitioners. Using self-evaluation as a tool to reflect and then by finding the best possible cross-sparring partner, the process results in the generation of effective development plans that are focused on producing more dynamic, engaging and effective engineering education.

2 Objectives

The objectives of the approach are to support continuous quality improvement, both enhancement and assurance, by identifying an improvement plan and sharing working practices from different programmes in different universities. This process of sharing and critique based on the quality assurance metrics adopted in producing the self-evaluation framework, have been shown to promote reflection and planned steps toward a more relevant and engaging engineering education provision (enhancement). This also leads to a more practical quality assurance model that is able to sustain continuous reform between accreditation rounds.

3 Background to the Project

The European Commission Report on ‘Progress in Quality Assurance in Higher Education’ [1] underlines the importance of developing a quality culture in higher education institutions. It points to the value of institutional evaluation which it states “empowers academics and HEIs (Higher Education Institutions) to build curricula and to ensure their quality, avoiding the need for formal, external accreditation of each individual programme”. Responding to that statement, eight European Universities:

- Reykjavik University (RU), Iceland
- Turku University of Applied Sciences (TUAS), Finland
- Aarhus University (AU), Denmark
- Metropolia University of Applied Sciences (Metropolia), Finland
- Umeå University (UMU), Sweden

- IMT Atlantique (TB), Institut Mines-Telecom, France
- Aston University (ASTON), United Kingdom
- Queens University Belfast (QUB), United Kingdom

have been working together for two years developing and piloting a practical tool box for enhancing the quality of engineering education at the programme level. Prior to this project some of the participants had worked together in two different regional projects to lay the foundations for this larger project. In those earlier projects it became clear that the foundation for continuous improvement originates in a good understanding and shared vision of the present situation in the unit being considered. In addition to that understanding, external experience of the options and possibilities available for future development and change are needed. Thus from this earlier work, the goal of the new project became clear - to create a platform for engineering education programme teams to find critical friends for helping in the development and enhancement of the programmes identified. Before entering the platform, programmes need to go through a guided self-evaluation to be able to produce the necessary data about themselves and their programme for a suitable critical friend (to be identified) to review and consider, in order to form a mutually beneficial contact. In Fig. 1 the overview of the newly created platform (QAEMP – QA and QE Market Place) is presented.

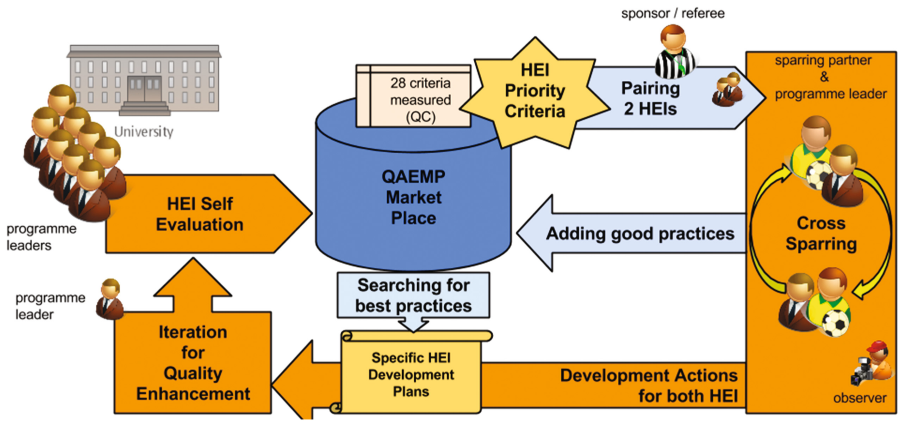

Fig. 1. Overview of the QAEMP toolbox [11].

The entire toolbox consists of a self-evaluation questionnaire with guidelines on how to use it, a software based pairing tool, guidelines for preparing and executing the cross-sparring exercise following the pairing and finally proposals for how to implement the development activities identified during the process.

This paper reports on the experiences of the project team. The funded project is now finished and the aims have been realised with the production of the self-evaluation tool and the on-line market place for programme teams to find cross-sparring partners to match with for quality enhancement opportunities within their programmes.

4 Methodology

At the outset of the project a selection of the most relevant engineering education accreditation and evaluation standards were studied for the development of the self-evaluation tool [2]. These included, for instance, the CDIO Standards [3] and the EUR-ACE Framework [4]. These two examples were particularly relevant as the project partners were all from Europe and particularly interested in the CDIO (Conceive Design Implement Operate) Approach to engineering education. The other QA Systems considered as part of the project are identified in Fig. 2 and cover the relevant international documents as well as the national approaches from each of the partner countries.

• CDIO Standards and Rubrics • EUR-ACE Framework Standards • ABET- United States • CEAB- Canada • Engineers Australia • UK Quality Assurance Agency • Aston University specific processes for Annual and Periodic Review • UK Spec Accreditation • Danish National Standards • Finnish National Standards • Metropolia Self Evaluation • Turku process	• French National Standards • Irish National Standards • QUB Educational Enhancement Process • Iceland National Standards • Quality Enhancement Handbook • OWLS Project • IMechE Accreditation • Royal Aeronautical Society Accreditation • EFMD (Management Education)

Fig. 2. The set of QA Systems considered in the development of the Self-Evaluation Tool.

Based on the different questionnaires and approaches to self-evaluation in these systems, a new set of questions focusing on the enablers of excellent education was created. Questions concerning finance and management were left out as these were deemed outside the learning and teaching focus of the project. The result of this synthesis was a questionnaire comprising 28 questions. In considering how partners should respond to the 28 criteria, it was decided to adopt a maturity model approach similar to that used in the CDIO Standards. This approach requires the self-evaluation respondent to identify the statement that satisfies the state of maturity that their programme has reached at that point in time in response to a particular question. The statements develop from 0–5, each one building on the previous one. If a respondent can state that 0, 1 and 2 have been fully met, and that elements of statement 3 are also true, but not all of 3, then the maturity level rating for that particular response will be 2. 3 will only be achieved when full compliance can be stated. The definition of the maturity model based rubrics and application of the self-evaluation have been presented earlier [2]. For completeness an example is given below (Fig. 3).

A Holistic View of Learning
Rationale

For an effective learning experience it is important that the different components of the programme are linked together in a meaningful way. That way the student has the potential to gain a complete understanding of a discipline and consider potential career options. To achieve this, the programme team need to reflect on the programme structure and content to ensure coherency in the meeting of programme goals.
Rubric

Level	*Description*
5	*The programme team continuously improves and develops the process that ensures reflection on the programme structure and content to ensure coherency in the meeting of programme goals*
4	*The programme team has evidence of the implementation of a process that demonstrates reflection on the programme structure and content to ensure coherency in the meeting of programme goals*
3	*The programme team is implementing a process that ensures reflection on the programme structure and content to ensure coherency in the meeting of programme goals*
2	*The programme team has a plan to implement a process that ensures reflection on the programme structure and content to ensure coherency in the meeting of programme goals*
1	*The programme team is aware of the need for a programme with a structure and content that ensures coherency in the meeting of programme goals*
0	*There is no reflection on how the programme structure and content play a role in meeting the programme goals*

Fig. 3. An example self-evaluation question and rubric [11].

The 28 criteria were not produced in one review and analysis of the literature. Having identified a series of initial questions, the project team reviewed and discussed the proposal and after two iterations settled on the final 28 (Appendix A). The self-evaluation results based on the 28 criteria and generated by each partner were entered into the online 'Market Place' tool which pairs the participants according to their developmental priorities. These developmental priorities were identified from the self-evaluation but institutions were also able to identify specific areas that they were most interested in improving.

As well as the development priorities, the pairing is done by calculating the distance between the scores of the 'learn-and-inspire' criteria (identified questions) from the self-evaluations. As an example consider the following part of a set of self-evaluation results in Fig. 4. The numbers are the scores derived from the relevant maturity rubrics (0–5).

Criterion	Institution A	Institution B	Institution C
1) A holistic view of learning	4	2	1
2) Appropriate learning outcomes (developed from required competences)	3	4	3
3) An integrated curriculum	2	4	3
4) A sound subject foundation	1	4	3
5) Active learning approaches	3	3	5
6) Appropriate workspaces and equipment	3	3	3

Fig. 4. An example of pairing according to the self-evaluation results [11]

The grey cells are the 'learn-and-inspire' criteria identified by the institutions concerned. Here the distance would be 7 between A and B, 6 between A and C, and 3 between B and C. The distance between A and B is 7 since the 'learn-and-inspire' criteria involved are 1, 3, 4 and 6. The distance in learn-and-inspire criterion 1 is 2 (4–2), criterion 3 is 2 (4–2), criterion 4 is 3 (4–1) and criterion 6 is 0 (3–3). The best match will then be A and B. This is based on the premise that the best match will occur when the chosen developmental criteria of each institution has the biggest difference.

After pairing, the institutions exchanged the self-evaluation reports and studied the background information of each other's institutional and programme environments. Many valuable development ideas and suggestions for educational enhancement were then identified and used to stimulate action plans for implementation [5–8]. The whole process is illustrated more fully in the flowchart presented in Fig. 5. Site visits to each partner institution were then planned and executed based around the identified developmental criteria.

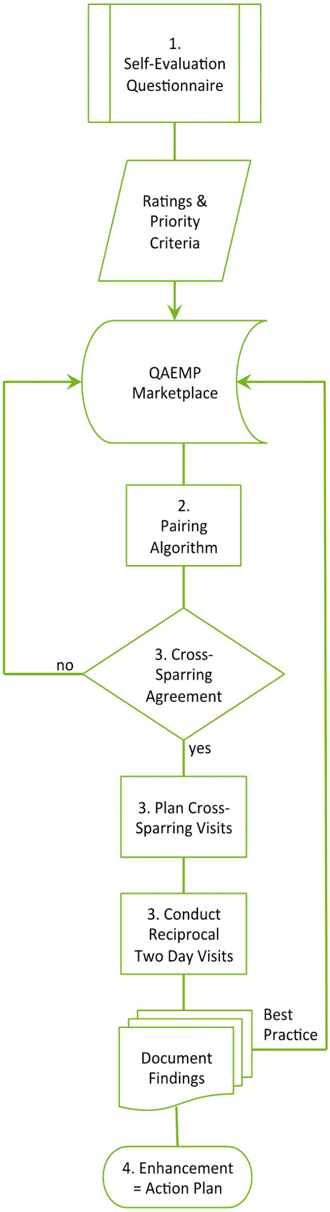

Fig. 5. A flow chart illustrating the full process [11].

Some additional detail on the different elements of the process are now presented.

As part of the self-evaluation process it has been important to gather the argumentation and indicators used to justify the maturity scores. This has allowed for the development of the self-evaluation tool and is required for the partners to benchmark their individual interpretations of the self-evaluation rubrics. This element of the process development is ongoing and will remain so as more institutions make use of the process.

Paired institutions had to come to a mutual agreement that they wished to continue to the cross-sparring phase before any further work commenced. In consultation with one another, plans were then drawn up for the visits to each of the cross-sparring partners. This required the following:

- A review of the priority criteria and identification of 5 criteria on each side to be used as the focus of the visit
- Drawing up of a detailed timetable of activities to examine the practice in each priority area.

5 criteria were chosen by each partner as the initial basis for the discussion and visits as it was felt that in 2 days (the visit duration) any more would have made a coherent and practical action plan for each partner difficult to produce. 5 criteria allowed a focus for each visit yet a depth of exploration that would stimulate ideas for action.

Travelling to each other's institutions allowed the participants to observe first-hand how the criteria are managed/delivered and the environment in which they were operating. These visits helped ensure a depth of understanding and knowledge was gained.

A single pro-forma document for each institutional visit was completed by both parties together to capture this new learning. After both visits, each institution compiled an action plan for self-improvement based on their cross-sparring experience and the insights gained.

5 Cross-Sparring (CS)

For the cross-sparring, the first step was the pairing of the programmes. As stated earlier, in the pilot phase of the project two elements were considered: the priority areas for programme improvement and the rating scores that resulted from the self-evaluation exercise in each institution.

The CS itself is composed of four main activities:

- Initialisation – participants from each partner institution agreed on their own priority criteria (for enhancement) from the self-evaluation work and the focus, boundaries, roles, responsibilities and composition of the CS team. This activity was conducted in advance of either of the two visits
- Organisation and Preparation – the team detail, the self-evaluation results, the visit agendas and production and validation of the CS plan are shared and agreed
- Sparring – at each institution, during the visit, the partners identify evidence related to the priority criteria, best practices, challenges and potential improvement actions
- Feedback and Development Plan – reporting of the visit findings to ensure the action focused objectives of the project can be embedded in each institution.

The 8 participating universities in the project made up 4 pairs for the cross sparring process. Below is a brief account of each pairs experiences, some very positive, some less so.

Pairing 1 - Umeå and Queens Belfast

As a first example, in Fig. 6, Umeå University and Queens University Belfast were paired together. Belfast had chosen their priority criteria to be the numbers 1, 2, 7, 9 and 18 while Umeå selected the numbers 5, 8, 16, 23 and 25. In general, the criteria are chosen so that one university has a higher score in the self-evaluation for the criteria identified than the partner university. The universities also had an opportunity to select a set of priority criteria in which they were particularly interested in improving. If a match was not possible to find taking into account the priority criteria, they were relaxed until a match could be found. The pairing needs to be chosen such that each partner has the maximum opportunity to benefit.

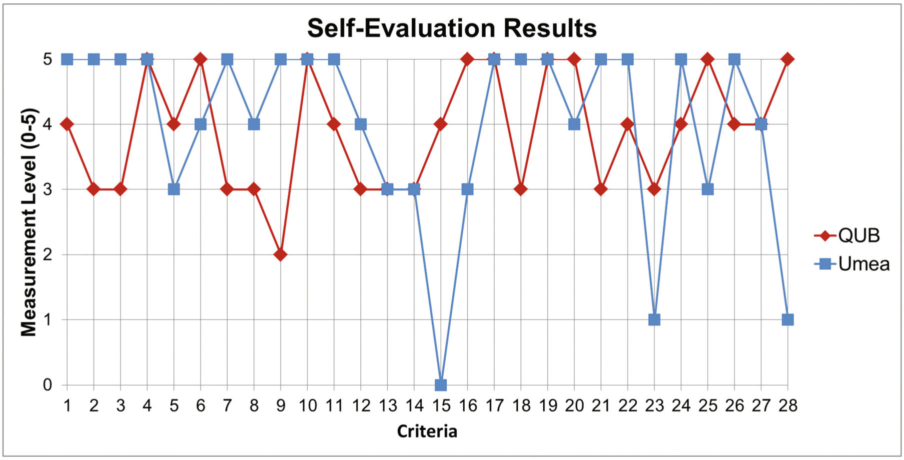

Fig. 6. Self-evaluation – determining priority criteria [11].

This set up of the site-visit has a win-win objective. Those that have something to share can do so and those who want to learn can do so. Starting from the selected criteria the site visit was planned as a series of presentations, meetings, visits to labs etc. to, as best as possible, show why the host university had scored themselves at the level they had. After the first visit in the Umeå-Queens cross-sparring a short session of explaining the national educational system and local structures of the university was added. The reason for this was to enable some understanding of why things are done the way they are. When evaluating the cross-sparring one of the participants stated: “this is like going to a tailor made conference, with only very interesting sessions.”

In most cases the selection of the priority areas was based on where an institution rated themselves low against the maturity rubrics. This captured their desire to improve their capability in that particular area. In some cases the partner institutions scored the priority areas similarly, thus allowing for a fruitful discussion to take place that would lead to the opportunity for mutual improvement [5].

Pairing 2- Reykjavik University and IMT Atlantique
In order to learn from the experience of others, IMT Atlantique (Telecom Bretagne programme) in France and Reykjavik University (RU) in Iceland chose to engage in a pilot study for collaborative quality enhancement in engineering education by sharing institutional best practices. A collaborative quality enhancement experience took place in the fall of 2015 between the two institutions.

In the pilot study, each institution chose the criteria on which it wanted to improve and visited the other to learn about best practices and seek advice from the other. RU wanted to learn and improve on integrated curricula including design projects, different learning styles, and technology to engage students. IMT Atlantique wanted to learn and improve on workspaces and equipment, learner assessment and formative feedback, student progression monitoring, and communication with students.

Reykjavík University is the second largest university in Iceland with about 3,200 students and 250 employees. RU consists of four academic schools: School of Law, School of Business, School of Computer Science and the School of Science and Engineering. IMT Atlantique is a flagship of the Engineering Grandes Ecoles in France, with about 1400 engineering students and 300 PhD students (730 graduate at Masters level each year), 500 permanent staff, including 290 (associate) professors, which is an excellent staff/student ratio for France.

The nine criteria, which the institutions had prioritized for improvement, were investigated during the two cross-sparring visits. A strong effort was made by each institution to show their good to best practices, as reflected in the agendas of both visits. At IMTA, there was a total of 15 items on the agenda and a total of 14 people made presentations or had discussions with the visitors from RU. At RU, the corresponding numbers were 11 items on the agenda and 22 persons that interacted with the visitors from IMTA. On both sides the focus was more on the results of the self-evaluation than the processes in place for monitoring continuous improvement.

With only two days, a hectic learn and inspire agenda, and nine criteria to focus on, it clearly emerged that the scope was too broad. The mass of information received was hard to follow and make sense of, hence this generated an unfocused report. Each time the team met someone, they forgot the focus of the analysis. Many constructive exchanges took place during the two visits, including first discussions about exchange agreements between the two institutions. Research in engineering and technical science was also under the spotlight. Many topics that were outside the focus of the visit were discussed, e.g. gender and intercultural issues, students living facilities, faculty training and academic career paths, research labs, economic issues such as tuition, national budget, incomes, etc.

During the visit to RU, other programmes than the one under consideration were also discussed, i.e. a large part of the discussion was at an institutional level rather than at programme level. Both institutions found it quite easy to capitalize on the others good practices for their own context, but much harder to report or give good advice on their obstacles or difficulties. Even if all partners were open-minded, visitors were not expert counsellors and the cultural dimensions needed to be taken into account. Recognized by both participants, having the opportunity to meet students during the visits was more than instructive. Such meetings without the presence of local faculty, allowed the visitors to learn much more about, and get insight into, the student perception and implications regarding feedback and course evaluation. The students comments were more than valuable for transfer to the partner institution, due to a more open and reflective discussion with external visitors [6].

Pairing 3 - Aston and TUAS

The cross-sparring exercise between Aston and TUAS was seen as extremely positive. As mentioned elsewhere, the partners felt that having a mix of disciplines between the partners allowed the participants to focus much more clearly on the overarching learning and student development needs rather than focussing in on narrow and technical discipline specific matters which might have been the temptation otherwise.

From an Aston perspective, staff recognised the increasing emphasis on employability within their own context and were able to be inspired by a number of activities at TUAS, most notably a range of entrepreneurial and spin-out support opportunities for students both during their studies and on graduation.

For Turku, Aston were able to advise and demonstrate their experience in the use of technology to support students, including lecture capture, interactive support material and online resource.

The partnership also demonstrated the benefit of the international dimension of QAEMP. Aston has an extremely culturally diverse student body which very much reflects a highly diverse local community in the UK Midlands. TUAS as with much of Finland has traditionally had a much more monocultural student body however had recognised that this was changing and with diversity of the student body becoming increasingly important they were able to call on Aston's experience in this area.

Overall the partnership was seen as a success which has led to positive developments and proposals going forward both for each University individually and also in partnership [7].

Pairing 4 - Aarhus University and Metropolia University of Applied Sciences

Metropolia had been involved in the previous projects of this type and thus was very enthusiastic in participating in QAEMP. There was additional motivation for the Metropolia staff members when they realised that the cross-sparring partner in Aarhus was working in the same discipline area. In Metropolia the self-evaluation had been done in a group by 6 staff members. The group needed 6 h of work together. Before that stage everyone had done the self-evaluation individually. It was clear that even at the self-evaluation stage, many development actions were being identified.

The meetings in both universities were carefully planned - having time for formal discussions, asking questions and thinking. Additionally the relaxed time in between the sessions was used for meeting students and other staff in a more informal way. The result was that a comprehensive picture of the activities in the other university was created.

When developing the QAEMP process further, the partners felt it would be important to ensure that the students' role in the evaluation phase be extended. Students can help the evaluation "to think out of the box" and to create totally new ideas viewed from different perspectives. Some of the ideas may be impossible, but some might lead to surprisingly innovative developments.

In this pairing, concrete outcomes to the pedagogical and organisational issues were realised. Furthermore, the programmes belonging to the same discipline was viewed as a positive feature as content issues were also able to be discussed. This allowed for future cooperation in projects and courses to be explored. This was considered as adding additional value, as it combined the interests of the quality management experts and the content experts.

One of the major areas of interest was the introduction of a common first year for all study programmes with a major IT component included. The participants had detailed discussions about the pros and cons of this approach. At Aarhus University it was decided that this was not the way forward since one of the consequences was a major drop in the intake of female students. However, Metropolia's strong focus on the well-being of the first year students proved an inspiration. At Aarhus as they have a project each semester, their intention is - inspired by Metropolia - to put a more systematic monitoring on student's engagement and well-being by the project supervisors thus helping to ensure a positive and supported first year experience [8].

6 Discussion

The idea of cross-sparring is seen as a productive way to facilitate study programme development. The pairing of the partners demonstrated the potential to generate a wide range of creative and productive ideas based on the different strengths and contexts of the institutions involved. The optimum case would see the cross-sparring sustained beyond the "one hit" such that the institutions become mutual mentors to each other and identify opportunities for ongoing collaboration and support.

One such example from the project resulted from the Aston – Turku pairing in which each institution identified the need for further work in the area of staff development and training to support the implementation of active learning in each institution. The recognition of this need has resulted in the generation of a brief for a collaborative project exploring the needs, existing resources, the generation of new resources and a delivery phase that will also encourage staff exchanges and a series of shared workshop experiences.

The cross-sparring model was developed to complement the accreditation system in each context and facilitate the dissemination of best practices in quality enhancement and engineering education among HEIs. The identification of best practices takes place when the cross-sparring is conducted. Institutions come together to learn from each other as partners for a short period of time rather than as competitors. They are given the opportunity to identify their sparring-partner's strengths and challenges free from bias in order to provide more immediate feedback for development actions. An effective external collaborator (cross-sparrer) can help a partner institution (cross-sparree) reflect with greater impartiality and obtain a more objective view of its strengths and potential areas for improvement, and at the same time identify best practices that can be useful for their own institution.

In addition to the indicators to support the maturity rankings, the ideas and examples of best practice are going to be used to create the next iteration of the self-evaluation tool and the content of the QA and QE Market Place. By doing this, the self-evaluation document will provide additional guidance to the programme teams completing the self-evaluation exercise and ensure greater consistency in the rankings produced. In addition the on-line Market Place will become an archived database of good practice and evidence that users will be able to access and reference.

Discussion is continuing on how future pairs should be matched. In the future it might be beneficial to give the participating units an opportunity to identify their preferences not only based on the evaluation criteria, but also based on the match of discipline. In this piloting phase the mismatch in disciplines between QUB and Umeå (Mechanical Engineering and Software Engineering) proved to be beneficial and not a shortcoming. This was because the partners were able to focus on the features of the learning and teaching and were not distracted by discussions about content. The Aston – Turku pairing shared this view. On the other hand, Metropolia found it very beneficial to have Aarhus as a cross sparring partner as both focused on a programme in Health Care Engineering and thus got useful ideas about developing the content of the programme as well as the learning and teaching process identified in the self-evaluation. Reykjavik and IMT Atlantique reported the benefits of having different disciplines, as then the cross-sparring was really concentrating on the issues raised by the self-evaluation without the pressure to consider the content of the teaching. Where Reykjavik and IMT Atlantique did experience problems was in the understanding of each other's educational systems. The private v public differences and the general environment in which each institution operated required time to understand and thus had an impact on what could be accomplished around the identified priority areas.

Rating dimensions and progress in terms of objectives and indicators permits institutions to compare several educational programmes without the need to rank them. As shown in the context of QAEMP, a fair evaluation should not be limited to teaching and learning methods or curricular content. The QAEMP approach to evaluation is multi-dimensional and thus has a full emphasis on development and continuous improvement.

More work and experiences are needed to create a fully working 'Market Place' to fulfil the needs of different programmes. Figure 7 illustrates the goal for the Market Place to be a database of programmes which have submitted their self-evaluation reports and priority areas. As a new programme joins, its information is compared to the information already available and the best match will be offered to the programmes as potential cross-sparring pairs. One consideration will be the time for which a self-evaluation will be considered current such that all potential cross-sparrings identified are valid.

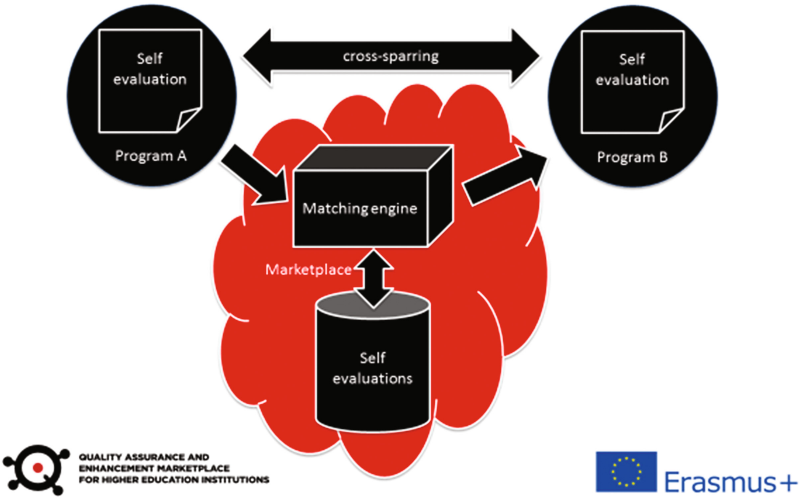

Fig. 7. Cross-sparring market place [11]

7 Conclusions

In this paper, the authors have introduced a cross-sparring model and offered their initial thoughts on the strengths and weaknesses of the model and process. This paper builds on the workshop held [9] and paper [10] presented in the WEEF2015 conference in Florence, Italy in September 2015. The combination of a self-evaluation and cross-sparring is seen as a process that promotes reflection and dialogue and that unlocks a larger range of opportunities for enhancement than if an institution were to remain inward looking and conduct the exercise alone. The reflective enhanced self-evaluation used in this project is a powerful and objective tool.

The overall cross-sparring principles of the QAEMP project were met: to get to know each other, to learn and inspire each other, to be “critical friends”, to openly evaluate and analyse rather than audit. Learning from others and sharing best practice showed that it is a valuable medium for improving educational quality, and thus performance. The pilot cross-sparring allowed the project team the opportunity to test the models and tools created such that they can be used further in the future.

For the most part the approach was viewed positively in each of the participating institutions when considering colleagues outside the project team. The QAEMP approach is very much seen as something to complement the current QA processes in the institutions. If embedded and used to best effect, the QAEMP process has the potential to support the existing QA in a major way whilst at the same time promoting QE.

The dissemination conducted to this point through presentations and active workshops has generated considerable interest and the hope is that future funding will allow for the further use and development of the outputs from this project. Some areas of the work that will need further thought concern the need to ensure that the use of the process remains practical and does not significantly impact programme team time and resources.

Some institutions did find the self-evaluation process lengthy, despite also highlighting its value both in the short and long term. Balancing the visit length and cost versus the priority areas to be addressed was also a topic of discussion within each pairing. The argument from this would be that once a visit has taken place, however short, follow up on additional priority areas would then be more easily accomplished via electronic means such as e-mail exchanges and the use of skype or an equivalent.

Embedding and committing to a plan for development within the institution is the ultimate test for the success of the QAEMP process. Each of the 8 institutions have started the first steps towards making this happen and in some cases the relationships will likely develop around specific projects and areas of mutual developmental interest. By engaging in this process, each institution sees the experience as contributing to their statutory QA requirements, but in a way that keeps QE firmly in the minds of all involved.

As the project concludes, engineering programmes around the world are invited to use the self-evaluation created as part of the project and to then enter their results into the on-line Market Place. The more programmes there are that do so, the greater the selection of possible cross-sparring partners for participant institutions will be. It is important to invest sufficient effort in the process from the very beginning though. In the case of this project there was a good combination of strengths and development areas identified which has resulted in a solid foundation for the on-line Market Place.

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Appendix A - The 28 Criteria in the Self-evaluation [11]

Full descriptions and rubrics can be found in the Self-Evaluation Manual (www.cross-sparring.eu).

(1) A holistic view of learning
(2) Appropriate learning outcomes (developed from required competences)
(3) An integrated curriculum
(4) A sound subject foundation
(5) Active learning approaches
(6) Appropriate workspaces and equipment
(7) Personal and interpersonal skills development
(8) Faculty development (knowledge and teaching)
(9) Learner assessment (type, level and amount)
(10) Programme evaluation to promote continuous improvement
(11) Links to employability are made throughout
(12) Collaborative learning
(13) Additional support for learning
(14) Technology to engage students in learning
(15) Feedback is timely, appropriate and formative
(16) Research is used in teaching
(17) Student participation in programme review and development
(18) Wider stakeholder input to programme development
(19) Student retention and progression is monitored
(20) Work placements are promoted
(21) Problem solving opportunities (links to the research process)
(22) Design projects are integrated throughout the programme
(23) Equality, diversity and equal opportunity considerations are part of the programme team thinking
(24) Professional attributes and topical considerations are part of the programme
(25) Evidence of educational scholarship by faculty
(26) Effective communication with students
(27) Different learning styles are taken account of
(28) Teaching resources

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Equity and Diversity in Engineering Education

Introduction to Equity and Diversity Section

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Equity and diversity is an important issue in engineering education, especially in developing smart societies required for Industrie 4.0. This section contains six chapters that dwell on issues in diversity, such as gender, as well as efforts in creating equity in engineering education.

Narasimhan et al. described observations on the tendency to attach gender classification to certain fields in their chapter, "A Subjective Examination of Implicit Root Stereotypes of STEM Disciplines". Using the examples of Physics and Software Engineering, recommendations are made to help increase the participation of women in STEM fields.

Phang et al. presented in the chapter entitled "Perception on Complex Engineering Problem Solving among Engineering Educators", a study to investigate the understanding of engineering faculty members on the attributes of complex engineering problems, a necessary outcome for engineering graduates in this era. The study revealed the lack of understanding on complex engineering problem attributes among faculty members, calling a need for proper training to attained the outcomes required by the Washington Accord.

Marques discussed about the underpinning theories of vocational and technical education that can transform graduates for nation building in the chapter on "Theoretical Foundations of Vocational and Technical Education and the Part They Play in the Process of State Building". He argued that the classical behaviourist principal is not sufficient to develop the whole range of learning needs to produce graduates required for nation building. The constructivist approach, on the other hand, will be more relevant in developing these skills and especially the thinking skills required for the smart societies.

Helmi et al. put forth a review on the implementation of Multi-Criteria Decision Making (MCDM) methodology in engineering education in the article, "MCDM for Engineering Education: Literature Review and Research Issues". To improve the management of engineering education, the review in this paper was concentrated on seven engineering education decision making problems: resources allocation, performance measurement, budgeting, scheduling, planning, obtaining resources and evaluation

Garcia and Pinella, in the chapter on "Engineering Challenges in Terms of Academic and Professional Training", elaborated on the types of challenges to develop global and multidiscipline engineers for equity in a Smart Society. In addition to technical training and knowledge, they included economy, environment, technology of informatics and communication, soft skills, moral and ethics.

Finally, Delaine et al. in their article entitled "Leveraging Professional Networks for an Equitable, Smart Society - A case study on the International Federation of

Engineering" documents the efforts of the International Federation of Engineering Education Societies (IFEES) in leading engineering education into the 21st century. Having gone through its first ten years, the mission and vision of IFEES and action plans for the next decade in engineering education to attain an equitable society are shared.

Theoretical Foundations of Vocational and Technical Education and the Part They Play in the Process of State Building

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Abstract. The theoretical foundations of Vocational and Technical Education are traced in various well-known studies. It would be helpful to scan those studies to gain a better understanding of what factors might be contributing to the development of Technical Education and the process of state building. The approach of classical behaviorist theory shows that it does not adequately address a full range of learning needs, which constructivist theory may address in a more comprehensive way. New studies have shown that Technical Education and the evolution toward higher technology in the workplace continue to advance. (Peter E., Doolittle. "Constructivism: *The Career and Technical Education Perspective*." Journal of Vocational and Technical Education. Volume 16, Number 1, 1999 http://ascholar.lib.vtedu/ejournals/JVTE/v16n1doolittle (accessed December 9, 2013)) Federal support for Technical Education must be on the redoubling of efforts to increase the links between not only academic and occupational skills development, but also between businesses and education. UNESCO has held group discussions with TVET (Technical and Vocational Education and Training) with members from developing countries to better integrate TVET programs. As a matter of urgency, attention should be paid to Technical Education due to both its impact on society as a whole and its influence on the process of state building.

Keywords: Technical education · Development · State building · Theory · Behaviorism · Constructivism

1 Theoretical Foundations of Career, Vocational and Technical Education

The relationship between State and Technical Education in general may be better understood through analysis of past studies on the theoretical foundations of Career, Vocational and Technical Education.

Preparation of workers for their entry into the workplace of the future and their subsequent career development necessitates an educational program that provides not only job skills, as enacted by Career and Technical Education throughout the 1900s, but also a higher order of thinking, problem solving and collaborative work skills. Classical behaviorist theory does not adequately address the latter kinds of learning but in contrast, constructivist theory may.

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In the 1900s, for over three-quarters of a century, the implicit learning theory of behaviorism stood at the vanguard of curricular and pedagogical research on Career and Technical Education. However, its counterpart, the theory of constructivism, has had implications for Career and Technical Education practice in recent decades and its abiding influence foreshadows future educational considerations. Cognitive constructivism balances most compatibly with Career and Technical Education. Here, Constructivist principles will be examined in the light of the fundamental requirements of Career and Technical Education as we move through the new century by examining new requirements for redesigned professions.

1.1 Social Efficiency as an Outgrowth of Education

One unifying theory binds social efficacy and human satisfaction. It was envisioned by David Snedden[1] and effectuated by Charles Prosser[2], Career and Technical Education in the US in the early twenty-first century became known as Social Efficiency Doctrine. Proponents of social efficiency held that only an efficient society could create a positive environment in which the individuals could prosper and find self-fulfillment.

Technical Education harbors an inherent mission to further the good of society by contributing to its efficiency. In the past, this fact would have been mentioned as one of the main characteristics of state building. Clearly, Career and Technical Education as envisioned by Snedden and Prosser, formed one of the bulwarks of social efficiency through its preparation of a well-trained and compliant workforce. It became a perceived *sine qua non* of an efficient society.

According to Snedden and Prosser, six fundamental theories form the basis for social efficiency.[3] They can be applied to both Career and to Technical Education, as in the early 1900s.

1. Socioeconomic stratification: In all societies, the natural development of social classes can be noticed. Movement between social classes flows though a stable social system and rightfully renders vertical social mobility challenging.
2. Probable Destiny: According to this theory, social classes are inherently stable. Thus, an individual born into a working-class family will probably live and die as a member of the working class.
3. Psychometrical measurement: This was seen as a potential predictive determinant of a student's destiny and was performed as a simple test. This classified educational tracks into academic or vocational and in turn augmented reliability.
4. The theory of social control: It affirms that for any society to exist, its members must voluntarily adhere to both implicit and explicit societal norms.
5. Pedagogy: Although never really formulated as a single coherent theory, pedagogy involved the systematic study of teaching and learning. According to Prosser and

[1] *David Samuel Snedden*, (1868–1951) One of the most prominent educators of the progressive era, and probably the most articulated advocate of social efficiency.

[2] Charles Allen Prosser, (1871–1952) was the father of Vocational Education in the United States.

[3] Ibid pp. 4–5.

Snedden, pedagogy for Career and Technical Education must be based on an organized, rigidly sequenced, hands-on approach to teaching.

6. Behaviorism: This provides the final foundation for social efficiency. (Research of E.L.Thorndile, 1932) It is based on the analysis of the human condition that relies on only verifiable observations of behavior and not on untenable mental construction.

1.2 Behaviorism and Moral Development

Further, behaviorists contend that most human behavior can be understood as basic reflexive learning mechanisms or “laws” that operate on one’s experience within the environment.

Behavioral science provided the processes by which schools would teach the right work and moral habits. It would lead to a voluntary compliance with social control theory.[4] It meant that members of all social classes would benefit from a healthier society and economy and, consequently a more humane workplace.

The educational system as an absolute contribution to social efficiency and development is influenced by the provision of a scientifically-based mechanism for teaching and learning. The aforementioned theories came into existence during the early 1900s and they would seem to have had little to do with the realities of the early 21st century’s Career and Technical Education. However, behaviorism remains the learning theory undergirding current Career and Technical Education thinking. Logically, it seems clear that a curriculum that is designed to provide specific, pre-determined skills demonstrated to industry standards does not represent knowledge constructed internally by the student, but rather represents externally imposed knowledge and skills.

Career and Technical Education at the local level remains oriented toward a competency-based curriculum, structured from the perspective of industry needs and standards, and delivered using a pedagogy that relies on pre-determined performance objectives. These objectives include conditions, tasks and standards. With the rapid development in occupational, educational and computer technologies, the old instructional model of transmitting to students a discrete and well-established set of skills and knowledge must be called into question. Within this uncertain environment of change, the students’ ability to build viable knowledge and to adapt is paramount. Attention to abstract reasoning, psychometrics and sociology would allow schools to guide students towards their ideal of education.

1.3 The Epistemology of Constructivism

Constructivism can bolster the theory and management of educational policy makers. Four essential epistemological principles of constructivism abide:

[4] Ibid pp. 6–8.

1. Knowledge results from active cognizing by the individual rather than passive accumulation.
2. Cognition is an adaptive process and functions to make an individual's behavior more viable, given a particular environment.
3. Cognition organizes and makes sense of one's experience; by processing that experience there is a more accurate representation of reality.
4. Knowing has epistemological roots both in biological/neurological construction and in social, cultural, and language-based interactions (Dewey, 1916/1980; Garrison, 1997; Larochelle, Bednarz, and Garrison, 1998; Gergen, 1995; Maturana and Varela, 1992).[5] Thus, constructivism acknowledges the learner's active role in the personal creation of knowledge, the importance of experience (both individual and social) in this knowledge creation process, and the realization that the knowledge created will vary in its degree of validity as an accurate representation of reality.

These four fundamental tenets provide the foundation for basic principles of the teaching, learning and knowing process as described by Constructivism. As will be seen, however, these tenets may be emphasized differently, resulting in various "types" of Constructivism.

2 Emergent Theories of Learning

2.1 Constructivism

New emerging theories of learning affirm the concept that learners construct their own knowledge from experience in an operation termed constructivism. In addition, recent research concerning Career and Technical Education has discussed the usefulness of constructivist principles without specifically positioning those principles within the framework of a constructivist perspective. Constructivism is a theory of learning that is rooted in both philosophy and psychology. The essential core of constructivism holds that learners actively construct their own knowledge and meaning from their experiences (Fosnot, 1996; Steffe and Gale, 1995).

Philosophically, this essence relies on an epistemology that stresses subjectivism and relativism: the concept whereby reality may exist separately from experience, yet can only be discovered and processed through experience, resulting in a personal reality. Thus, constructivism acknowledges the learner's active role in the personal creation of knowledge, the importance of experience (both individual and social) in this knowledge creation process and the realization that the knowledge created will vary in its degree of validity as an accurate representation of reality. However, these principles may be emphasized differently, resulting in various "degrees" or "types" of constructivism. Typically, this continuum is divided into three broad categories: Cognitive Constructivism (e.g., Anderson, 1993; Mayer, 1996), Social Constructivism (e.g., Cobb, 1994; Vygotsky, 1978), and Radical Constructivism (e.g., Piaget, 1973; von Glasersfeld, 1995).

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[5] Ibid p. 8.

2.1.1 Cognitive Constructivism

Cognitive constructivism represents one end, or extreme, of the constructivist continuum and is typically associated with information processing and its reliance on the component processes of cognition. Knowledge then, from the cognitive constructivist position, is the result of the accurate internalization and (re)construction of external reality. The results of this internalization process are cognitive processes and structures that accurately correspond to processes and structures that exist in the real world. This claim, that reality is knowable to the individual, differentiates cognitive constructivism from both social and radical constructivism (Fig. 1).

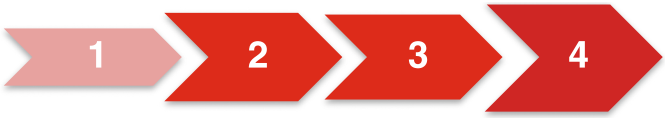

Fig. 1. The indicative emphases of the four essential principles (cognitive constructivism)

2.1.2 Social Constructivism

Social constructivism lies somewhere between the transmission of knowable reality of the cognitive constructivists, and the construction of a personal and coherent reality of the radical constructivists. Social constructivism, unlike cognitive and radical constructivism, emphasizes all four of the previously mentioned epistemological principles. These particular epistemological emphases lead to the definition of principles that maintain the social nature of knowledge and the belief that knowledge is the result of social interaction and language usage and, thus, is a shared, rather than an individual, experience (Prawatt and Floden, 1994).

In addition, this social interaction invariably occurs within a socio-cultural context, resulting in knowledge that is bound to a specific time and place. Truth is neither the objective reality of the cognitive constructivists nor the experiential reality of the radical constructivist, but rather is a socially constructed and collegially agreed upon truth resulting from “co-participation in cultural practices” (Cobb and Yackel, 1996, p. 37) (Fig. 2).

Fig. 2. The indicative emphases of the four essential principles (social constructivism)

2.1.3 Radical Constructivism

Radical constructivism represents the opposite end of the constructivist continuum from cognitive constructivism. Radical constructivism fully embraces the first three epistemological principles (1-2-3), that is, that knowledge acquisition is an adaptive process that results from active cognizing by the individual learner, rendering an experientially based mind, rather than a mind that reflects some external reality.[6] These particular epistemological emphases lead to defining principles that maintain the internal nature of knowledge and the idea that, while an external reality may exist, it is unknowable to the individual. Reality is unknowable since our experience with external forms is mediated by our senses, and our senses lack deftness at rendering an accurate representation of these external forms (e.g., objects, social interactions).

Radical constructivism has long been considered a "strong" form of constructivism, as it fully embraces three (1-2-3) of the constructivist epistemological principles and at least partially embraces the fourth. That is, radical constructivism is concerned with the construction of mental structures, the position of cognitive constructivists and the construction of personal meaning (Fig. 3).

Fig. 3. The indicative emphases of the four essential principles (radical constructivism)

3 Popular Requisites for Employability

Generally, theoretical research has shown that obtaining workers with an inherent work ethic and appropriate social behavior has been a priority for employers. Employers complain about the attitude and character of workers - particularly in relation to absenteeism, an inability to adapt, a lack of self-discipline and negative work behaviors. In response to criticism about the general employability of the workforce, the U.S. Secretary's Commission on Achieving Necessary Skills, in 1991 published a range of skills that everyone in the workforce should have. These include the following[7] (Table 1).

Table 1. List of necessary skills

1 Basic skills	2 Thinking skills	3 Personal qualities
a. Reading	a. Creative thinking	a. Responsibility
b. Writing	b. Decision making	b. Self-Esteem
c. Mathematics	c. Problem solving	c. Sociability
d. Listening	d. Knowing how to learn	d. Self-Management
e. Speaking	e. Reasoning	e. Integrity/Honesty

[6] Ibid pp. 7–12.

[7] Ashon D. Green, *History of Vocational and Technical Education* (book site) http://www.answers.com/topic/history-of-vocational-and-technical-education#ixzz2dE2hVgFF Gale Encyclopedia of Education (accessed January 3, 2014).

According to Constructivism, Career and Technical Education would prepare workers for skilled positions in the workplace through a public system of pre-employment, on-the-job training, skill-upgrading, and worker-retraining programs. To the extent that the role remains central to Career and Technical Education today, even within a changing society and workplace, certain practices must remain central in the professions. In order for Career and Technical Education to meet its obligations not solely to society but to the education community, to business, industry and to students, it must continue to identify employability and workplace skills and to pass on those skills to students. The precise nature of those skills may have changed from repetitive, manual tasks to problem-solving and collaborative tasks during the 1980s (McNabb, 1997), yet the fact remains that providing employability and workplace skills, is a fundamental goal for Career and Technical Education.

Viewing this employability and workplace approach through a constructivist lens, however, adds a new dimension of interest. Therefore, a new question must be asked

"How does Career and Technical Education merge the traditional need for learning core knowledge and skills with the modern emphasis on adaptability, knowledge construction and self-regulation?"

3.1 Traditional Learning Versus Knowledge Construction

Interlarding a strict commonly held approach to the learning of core knowledge with a pliant adaptive modern approach can be facilitated by an appeal to five central concepts:

1. All teaching within Career and Technical Education must begin and end with an appreciation of the student's understanding.
2. The student must be exposed to a core of currently accepted knowledge and skill sets within Career and Technical Education.
3. Career and Technical knowledge and skills have a dynamic; thus students must have the skills necessary to adapt.
4. The student's idiosyncratic understandings of Career and Technical knowledge and skills must be valued, as these understandings may lead to new discoveries, insights, and adaptations.
5. The goal of Career and Technical Education must be to produce an occupationally self-regulated, self-mediated and self-aware individual.

These five concepts provide a framework within Career and Technical Education that values historically reliable domain-specific knowledge, future innovation and change in domain-specific knowledge, and the thoughts and perspectives of the individual student and teacher. Career and Technical Education remains in fact, squarely grounded in the learning principles of behaviorism. Many scholars and reformers in the profession have supported changes that implicitly relied on cognitive constructivist principles. Scholars with new research have yet to explicitly address the shift from behaviorism to constructivism. As we move through the millennium, the path of theoretical reform adumbrates a changing reality. Behaviorist learning theory strains to adequately either explicate or predict the pedagogy needed by Career and Technical Education.

4 Technical and Vocational Education and Training (TVET): The Need for Reform

The UNESCO division of secondary Technical and Vocational Education affirms that often throughout recent decades, the skills imparted by the national education system did not match those demanded in the workplace. This has been evidenced in many countries and this mismatch has widened in recent years with the integration of new technologies in almost every sphere of professional activity. Most governments prioritize narrowing the gap between education and the world of work because of the potential economic and social benefits. It can increase the proportion of the population that engages in productive ways of making a living.[8] New studies show that the face of Vocational and Technical Education is changing, a phenomenon that presents challenges for the cultural traditional model. Levesque, Laven, Teitelbaum, Alt and Libera (2000) wrote that,

> "Historically, Vocational and Technical Education have had the role of preparing young adults for direct entry into the job market or labor pool with fewer credentials than college students."[9]

During the last one hundred years, the U.S. economy has shifted from manufacturing and industry to service and information. Elsewhere in the world, such as in China, Brazil and Russia, the economy has been shifting as well, requiring more skilled laborers and technicians. Due to the change in purpose of Vocational and Technical Education, in many countries, Vocational and Technical Education institutions are now becoming centers of research.

However, TVET is still considered inferior to a professional education or even relegated as a second choice, regardless of the students' interests or abilities. Many people, therefore, dismiss promising and meaningful career paths in areas where employment demand is greater, simply because of the perceived stigma attached to technical and vocational occupations. Education systems continue to be directed primarily towards preparation for university education.

4.1 China as an Exemplar

Wanbin Ren (2009) demonstrates that Vocational and Technical Education, in the case of China, should play an equal role of importance to academic higher education. Whereas third level education strives to cultivate engineering and academic professionals, the goal of Vocational and Technical Education endeavors is to produce skilled technical graduates. According to Ren, the importance of heightened attention to Vocational Education must take precedence as it will play a major role in fortifying

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[8] Unesco, "*Technical and Vocational Education and Training in the 21st Century*." United Nations Educational, Scientific and Cultural Organization, Last modified 2002. http://unesdoc.unesco.org/images/0013/001310/131005e.pdf. (Accessed February 10, 2014).

[9] Levesque K., Lauen. *Vocational Education in the United States:Toward the Year 2000 (NCES 2000-029)*. Washington, DC: National Center for Education Statistics, 2000. http://nces.ed.gov/pubs2000/2000029.pdf (accessed February 8, 2014).

China's sustainable development. Reform is exigent. As a generalized notion, he further stated,

> "China must replace the outdated idea that Vocational Education is a second-rate education with the new one that anyone with skills needed at the job market is useful".[10] (p. 155)

Vocational and Technical Education urgently needs reform in order to satisfy the needs of the growing service and information economy. Vocational Education specialists can no longer simply teach the skills, but also need to teach the special skills that labor markets demand. Vocational and Technical Education should be the means by which a country can develop and achieve the goals of science and technology. The evolution towards higher technology in the workplace continues to progress. In the interests of globalization, the focus of federal support for Vocational and Technical Education must be on the redoubling of the efforts to multiply links between academic and occupational skill development, and between secondary and post-secondary education.

The rapid technological developments we are witnessing in the 21st century, together with the forces of globalization, are resulting in radical changes in the world of work. In fact, the changing nature of work is already very noticeable in both urban centers and in rural communities. It follows, therefore, that human development, of which education is such a vital part, must keep in step with these societal changes if it is to achieve the goals of state building and development.

In past decades, UNESCO has held conferences with TVET policymakers and educators from developing countries willing to introduce or better integrate TVET programs in their countries in order to achieve more effective human resources development.[11] While guidance and counseling together form an easily accessible service in many developed countries, its benefits have yet to be adequately exploited in the developing world. In some countries such as Timor-Leste, it may even be considered a luxury that is postponed indefinitely in order to deal with more vital services that must be provided within ever diminishing budgets.

5 Pathways of Technical Education

Alan Smithers (2002) affirmed that the traditional curriculum is one of uniformity, and through this uniformity, all learners are treated alike. In so doing, schools lose the ability in curricular design to fit the specific, individual needs of learners; neither do they take account of their future needs nor the needs of the community. These communal needs equate with the means of the state wherein those future professionals will function. Smithers described three pathways of education for students entering secondary schooling:

[10] Ren, Wanbin, "*Thoughts on the solutions to problems in vocational education of the new age*." Asian Social Science. no. 8 (2009): 154–157.

[11] See, Unesco, "*Technical and Vocational Education and Training in the 21st Century.*"

1. One pathway academically directs students toward a degree with preponderance on coursework in mathematics, the sciences and languages.
2. The second pathway technically form students in design and interpersonal skills. The technical pathway develops problem-solving and imparts practical skills. It is based on the idea of general learning and includes many of the same subjects as the above mentioned academic path.
3. The third pathway is occupational. It is similar to the technical pathway, but more specialized and based on the work and the career the student wishes to follow. This pathway combines the educational setting, work setting and the paying of employers to participate.

Smithers depicted Vocational Education in England as lacking clarity and devoid of a complete path. He states that,

> *"The undervaluing of Vocational Education in British culture and lack of clarity about its purpose has impoverished both the education of the young and the quality of life of the nation".*

Young people suffer in their inability to develop their talents maximally while the country suffers *vis-à-vis* the inaccessibility to their practical skills.[12] He also suggested that governments pay more attention to Vocational and Technical Education because of how it impacts society as a whole.

6 Paper Analysis

This paper has highlighted the theoretical foundations of Vocational and Technical Education by tracing various studies. My intention in scanning those studies was to gain a better understanding of which factors may contribute to the process of state building. It has been shown that classical behaviorist theory does not address the many kinds of contemporary learning needs.

On the other hand, constructivist theory addresses more comprehensively the fact that Vocational and Technical Education and the evolution of technology in the workplace continue to advance. It is clear that constructivist theory fundamentally and wholly answers my research questions. Human resource development has benefited from contributions by TVET programs developed by UNESCO as it has from group discussions with TVET policy makers and practitioners from developing countries. As a matter of acute importance, increasing attention ought to be paid to Vocational and Technical Education.

Within the scope of this paper, it was not possible to present a full picture of Theoretical Foundations of Technical Education and relate them to the needs of contemporary learning giving an approach to more recent studies. It was however possible to construct and follow an argument on the proposed topic of giving an analysis on those theories. I hope this study represents some positive and conclusive remarks on the topic. This study, through the Theoretical Foundations, examined the necessity of

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[12] Smithers Alan, *Comparing standards academic Vocational,16–19 years olds*. London, UK: Vovcational education. In. S. Lawlor (Ed.), 2002.

technical education in the matter of state building. In order to give theoretical proof, this paper offers an approach of theoretical basis, regarding technical and vocational education in the beginning of the 21st century and the development of those theories up to the recent past.

Skills development in the formal and informal sector, especially in developing countries, is essential for poverty alleviation. Technical end Vocational Education in developing countries faces challenges in reform of government and non-government training institutions. Moving forward is a necessity and it requires the governments to be more strategic. The government is encouraged to foster partnerships with other providers, promote social equality, fill critical gaps and perform the market functions that the government is uniquely equipped to perform. Getting the policies right to encourage efficient training markets is an important first step. The implication for international assistance to skills development has been and is still of paramount importance. Upon closer examination, the above facts can show the impact and the vital contribution of theoretical foundations of Vocational and Technical Education to the building or the rebuilding of the state. However, in further studies there is a need to develop a more critical analysis of the theoretical foundations and to also analyze recent developments and their impact in the current context of Technical Education.

In many countries, it would be prudent to offer a combination of the three broad categories of Constructivism: Cognitive Constructivism, Social Constructivism and Radical Constructivism.

This aspiration plays out in the case of many countries, in the hope of its future impact on society as a whole and in particular as an influence on the process of state building.

Although this paper addresses the theoretical foundations set out in the beginning, much further research is needed in the area. It also does not pretend to be perfect or complete. As such, it is the basis for further research and studies that I intend to continue in the near future.

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Engineering Challenges in Terms of Academic and Professional Training

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Abstract. This article aims to present the challenges of engineering education in terms of academic and professional training based on what is considered to be needed and expected of a global and multidisciplinary engineer who can cope with the demands and the challenges of our world today, always with a vision towards tomorrow to contemplate future problems. The topics discussed are the following: The importance of knowledge about economics to propose effective and viable solutions, the ability to develop sustainable and short term solutions that solve the current problems of society, the demand for professional training required for insertion in the labor market, the promotion of research and new ideas, the development of creativity and soft skills, the need to manipulate and be aware of the latest information and communication technologies, the promotion of a responsible attitude towards the environment and the promotion of decision-making in the field of engineering based on ethics and universal morality.

1 Introduction

The notion of the word engineer that circulates today is that of an individual destined to the manufacturing industry, where his/her main function is to design, create and optimize both primary and direct consumption inputs, as well as the processes and machinery necessary for industrial production, including the design and optimization of public and private services. Thus, most engineering students are trained to perform specific functions in a local or multinational industry according to their technical skills and professional training. However, an engineer may hold positions within research groups, such as assistant or chief in areas where different kinds of knowledge are needed other than engineering such as administrative, economic, social, environmental, among others, as a teacher, as an active participant in the formation and execution of policies related to both the improvement of education in engineering and the quality of life of the population and defense of the environment and, perhaps also, as an entrepreneur, whether global or local, of industries which favor the economy of the regions, reduce the social gap and foster innovation, creativity and leadership in young people.

The continuous technological advances in information technology and communication over time have produced changes in the way of life, culture and societies' life quality. As a product of this, emerges the so-called global village where events and

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information of various kinds about a site, entity or person anywhere in the world can be public knowledge in a matter of seconds. On the other hand, while technology has positively influenced people's lives in certain ways, it has also enabled man to modify natural spaces on a large scale, destroying ecosystems, polluting the environment, using the resources inappropriately, especially non-renewable resources, and harming people's health. Added to this, disputes between people and nations today put at risk the security, welfare and global social order due to the growing development of technologies for military use and the insatiable struggle for leadership in the unscrupulous weapons race.

In this way, it is urged to train engineers who can operate efficiently and actively in the aforementioned areas. It should be noted that in order to carry out these tasks, not only technical and professional training in the field of engineering is indispensable, but also the knowledge of how it relates and interacts with the social, economic, human, administrative and environmental spheres.

On the other hand, far from considering engineering as a career opposed to careers related to the social and humanistic sciences, there arises the prevailing need to train engineers on questions related to ethics and morals, raising the awareness of young professionals about the impact and the consequences of their actions, not only as individuals, but also as part of an entity or a company, thus promoting sustainable development and actions that contribute to world peace.

Thus, the importance of this work involves not only the improvement of education in engineering but also how decisions taken at universities have repercussions in the daily life of people, political decisions, culture and life itself.

2 Theoretical Framework

2.1 Challenges Identified in Engineering Teaching

Engineering is the profession that leads the technological development either to create a product or provide a service, it goes beyond the technology developed for consumerism itself, it is essential to ensure a good quality of life for the citizens of a society in the 21st century and that is why the adequate training and performance of its professionals must be thoroughly controlled by the government and educational institutions.

For that matter, with the intent of showing the challenges of engineering not only in issues intrinsic to it, but also in all those with which it is related and, at the same time, in certain cases in which it also depends on, below is a brief interview with engineering students from Argentina and Ecuador on those challenges in terms of academic and professional training for an adequate performance of the engineer in any area in which he/she performs, whether academic, industrial, administrative, among others, presenting the degree of development of these challenges in their universities in order to promote the development of skills and knowledge in these areas. Forty students filled out the form which consisted of different sub-themes from which they judged the degree of development of them in their universities. Although the answers are subjective, the fact of obtaining successive coincidences gives them some objectivity that gives this work a considerable importance. The challenges of each section are valued from four prepositions: highly developed, developed, underdeveloped and non-developed. Thus, from the opinion of the students we will draw conclusions about engineering education in these countries based on the challenges proposed.

Economy. Engineers in training and engineering professionals often need to develop functions where knowledge and experience in economic issues are very useful, either when presenting a budget for research funding, enlargement of a factory or for the purchase of machinery, among others. In turn, knowing about finance, administration and industrial organization, together with the ability to understand in broad terms how the market works, will allow the young professional to work naturally, in a more dynamic and cooperative environment and with a certain leadership along professionals in the area of economics, and, why not, also aspiring to more senior positions in the company such as its management. Last but not least, knowledge and life experiences related to the issues at hand, along with a creative and innovative idea, adequate financial and market analysis and adequate capital, could become a promising manufacturing industry or service provider and, in a short time, an important source of work, hope for progress and better quality of life for many families, without forgetting that it would also be an important source of income for both the private sector as well as the country in which it is established.

The graph of Fig. 1 shows the opinion of students of engineering on the degree of development in the classroom of economic topics related to the professional practice in engineering.

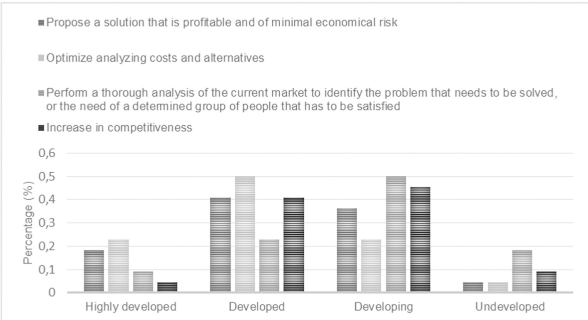

Fig. 1. Level of development of subjects related to the economy and related in the education of the degree in engineering

From Fig. 1 we can conclude that although the issues related to resource optimization and cost analysis to obtain an effective and viable engineering solution are well developed, there is still a gap, although not so extensive, to achieve satisfactory results according to the challenges posed. On the other hand, the existing gap in issues related to competitiveness and market analysis is quite pronounced and serious in these subjects on which universities should spend time in discussing their inclusion in the curricular space or in electives. The philosopher Casas (1970) refers to the indisputable practical purpose that man destines to knowledge:

> "…man, being simply in the world, lives immersed in a game of actions, tensions, impulses and elemental forces that drag him To a pure practical use of knowledge; Has the idea of being, without doubt, man also has the idea that things are, but this being of each and every thing is not seen in itself, but in a relationship of utility."

In this way it could be said that both technical and rational knowledge, from which a product or service is developed to satisfy some need, whether basic or superior or to solve a specific problem, arise from the Necessity, properly speaking, of man, who always creates and knows from a useful relationship, even when he does so unconsciously.

For this reason, an engineer can better perform his work if he knows the market in which he is inserted, that is, if he has knowledge about the needs and demands of the society where he lives to be able to propose solutions in the short term and with good results on the problems it faces. This task is achieved through an intellectual process that, with limited resources, culminates with the discovery of an optimal solution technically and economically. In turn, knowledge about macro and micro economy will allow the engineer to develop skills to improve competitiveness and productivity in the field in which it is developed. Thus, the economic factor becomes indispensable since each citizen has his role in society where all product and service has its cost according to the supply and demand internationally and locally, so, you cannot talk about engineering without before having talked about economics.

From this point of view, it should be noted that being aware of economic issues will allow the engineer to know their economic limits, beyond those of the own trade, and this would not imply an impediment to obtain an effective and viable engineering result but a challenge to make this result effective, with rather minimal cost and environmental impact, not only with the objective of achieving the maximum monetary benefit in the company or institution in which he/she works but also to make technology more and more accessible for your community.

Society. Humanity, in general, lives under a system of organization where each member brings their knowledge and their workforce in a certain area to obtain remuneration with which to satisfy their needs. This system has allowed man to impose himself in the world in front of nature, to know himself, to improve his quality of life, to spend more time studying his environment, to develop his curiosity and his technical and rational capacity. Thus, since it does not have to worry directly about the satisfaction of its basic needs like food, clothing, among others, part of society can dedicate itself to the study of the world and the universe, to the development of new technologies, to the administration and organization of government systems, education, health care, entertainment, etc. In short, beyond the fact that some jobs are better paid than others or have greater relevance for the common people, all are necessary to contribute to the welfare and progress of our society. In particular, engineering has become an indispensable part of almost every aspect of life, from the production of fuel for the transportation of passengers, because in exercising his profession not only do they bring knowledge and skills and products from and to the whole world, to the mass production of vaccines, food, appliances, clothing, among others. With this, it is emphasized that currently because of the great impact of engineering on the functioning of life in society, the work of engineers should not only involve the compliance of working hours and the directives of the company or institution in which they work, but in every action they undertake, they must strive to act according to the interests and well-being of their community but also assume a responsibility and a commitment to the people. Below is the degree of development of the social dimension in universities based on the opinion of students.

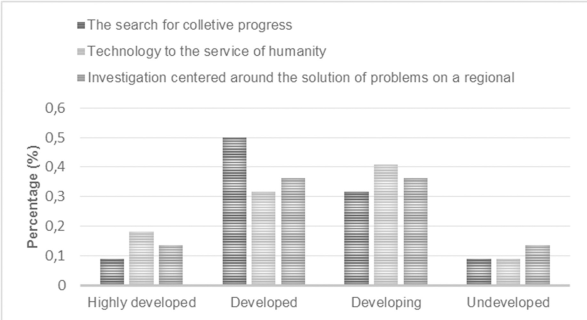

Fig. 2. Level of development of subjects related to the social dimension in the education of degree in engineering

From Fig. 2 we can conclude that topics such as the search for collective progress, the development of technology at the service of humanity and the approach of engineering to local communities are topics that could be addressed in greater depth in the classroom not only to combat the social gap but Also because the fact of thinking engineering solutions to concrete problems of daily life implies a challenge and a useful experience for young people in formation.

In universities, engineers are trained very well in matters intrinsic to their career, but in most cases the dictation of these subjects implies too much theoretical content, leaving aside the practical. In addition to this, the student is not encouraged to investigate and know how the theoretical concepts he learns in the classroom can be useful to solve specific problems in his city.

The feeling of belonging to the community by the student and the educational community, promoted by the university from research activities and action plans, will improve the lives of the people of the community and will give the young person knowledge and experiences of how to act in real life, where the theoretical is only a tool and what really has relevance is the practical use of the knowledge acquired to solve a problem with ingenuity. On the other hand, Miguel (2013), General Director of Scientific and Technological Activities of the Government of Buenos Aires, Argentina, in the forum "Impact of Engineering in Society" said:

> "Engineers are challenged to make solutions which are common to all, should seek solutions to issues that are not only local, but also open to information from all over the world."

It should be noted that international cooperation for the development of state-of-the-art technology, the acquisition of new knowledge on engineering and science and the pursuit of progress is of paramount importance. Thus, a work of an engineer or research group in China can serve its counterpart in Argentina and vice versa. In contrast, while we are seeking the collective progress of humanity, there are certain local issues that need special treatment and that depend on the natural and cultural conditions of the place, information that engineers must know and be able to handle whenever the need to act locally may arise.

Finally, since engineering is a career that uses knowledge for practical purposes, that is, in a useful relationship, the mere study in universities of purely technical theoretical and systematic knowledge does not only hinder the work of engineers by the fact they don't have experience with their work environment but also limits the development of skills, knowledge and experiences related to the use of ingenuity and reasoning for the solution of specific problems at local and international levels. Thus, universities should stop considering that only technical skills are needed in the curricular space to train engineers of the 21st century, in contrast, it would be wise to incorporate workshops and optional subjects related to the topics mentioned. Every change of paradigm is questioned in its beginnings but humanity is in a continuous dynamism and those visionaries who see the need for change in advance to face the future will be the leaders of tomorrow.

Environment. Although every form of life contaminates the environment, nature itself has its own independent system of self-regeneration and natural selection that allows the prosperity of life in harmony. However, the man beyond seeking his survival undertook a way of creating that surpasses that capacity for self-regeneration of nature and, without neglecting all the elements that make human culture, any excess has its consequences and are already being felt. From the complete or partial disappearance of forests and jungles, the planet's lungs, through indiscriminate felling and urbanization, to climate change caused by global warming generated by the emission of greenhouse gases because of the massive industrialization of the planet. Engineering plays a key role in the development and improvement of technology to improve the quality of life of people, but has not taken into account the often irreparable damage to the environment and the socio-economic repercussions associated with it As a consequence of human activity.

Thus, the chart shown below, presents the opinion of engineering students on the degree of development of subjects related to the preservation and care of the environment and the development of sustainable technology in the classroom.

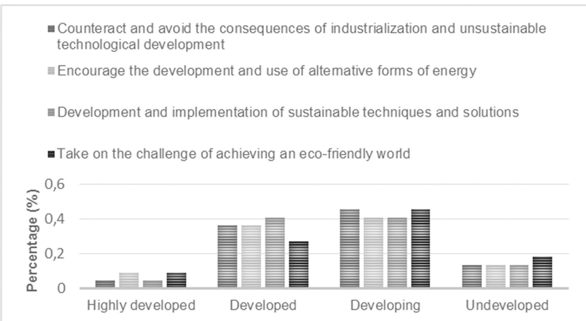

Fig. 3. Level of development of subjects related to the environment in the education of degree in engineering

From Fig. 3 we can conclude that issues such as the promotion of alternative energies, the development and implementation of technical and sustainable solutions and the idea of becoming an eco-friendly world are gaining some relevance in the classroom but not yet enough to face the undeniable environmental deterioration that our planet suffers and which has a negative impact not only on the daily life of the people but also on the flora, fauna and ecosystems of our planet.

At the World Engineering Convention held in Shanghai, China (2014), a relevant statement was issued, called the Shanghai Declaration on Engineering and the Sustainable Future, which expresses among other ideas that

> "…engineering and technology are vital in the direction of poverty reduction and sustainable development assurance, so engineers need to be aware of the need to balance the use of resources with the needs of future generations while maintaining the Environment and ecosystems, in order to promote sustainable development…"

In this context, today's engineering should seek to counteract "already produced" damage and seek the immediate cessation of any pollution or destruction of the environment which would endanger human life and health and the natural course of life on the Earth. To this end, it is essential to develop sustainable techniques, optimize the use of natural resources, research alternative forms of energy that are cost-effective but safe and clean to replace non-renewable resources such as oil and natural gas, and of course, respect the environment. This is the most important challenge of engineering and the world, since the future of our planet, and life on Earth as we know it, depend on it.

However, it is unfortunate that most universities in the world are not prepared to form sustainable engineers, either because of lack of educational policies, because of lack of interest by students and teachers, or because society is not prepared for it, a reality that can be reversed through the joint work of the government and the educational community.

Technical Training. University education prepares the engineer in areas of specialization and basic engineering subjects. However, an engineer must also acquire knowledge based on research projects, action plans-accumulated experience- and industrial practices. Parallel with the theoretical contents, Albert Einstein believed that the training of a professional should not be totally focused on promoting theoretical learning, because it is already available in a source of written information, therefore the value of vocational training must reside in developing reasoning ability to be able to give rise to innovative solutions. It is thus that the fact of relating the theoretical to the practical in university not only fosters the relations between universities and companies for an easy and efficient insertion of students but also gives them the confidence and the skills necessary to perform functions Related to their career efficiently, without fear and with certain leadership.

The following is the opinion of undergraduate students in engineering on the degree of development of topics related to academic training in the university.

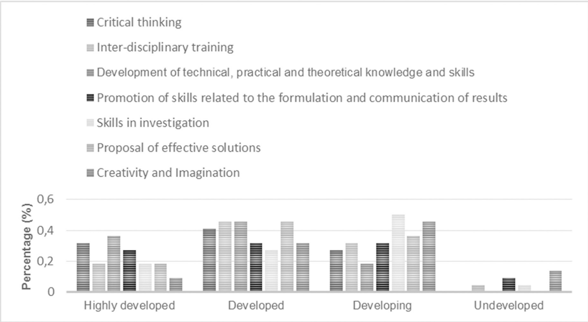

Fig. 4. Level of development of topics related to academic training in the university

From Fig. 4 we can conclude that topics such as the development of critical thinking, multidisciplinary work, the development of technical and practical knowledge and skills, and the promotion of skills related to the formulation and communication of results have some relevance in the Classroom but much more remains to be done to achieve optimal results. On the other hand, issues such as the development of skills related to performance in research work, obtaining effective solutions to specific problems and the promotion of creativity and imagination in the classroom are in crisis, despite these being the major contributors to technological development.

It should be emphasized that any engineering project must be backed by scientific and experimental knowledge that argues the hypothesis that arises, the experience and creativity that is possessed at the time of accomplishing this task is a great contribution. In this sense, the knowledge of engineering is indispensable to perform in it, beyond secondary knowledge and skills. However, the application of the methods, equations and programs addressed throughout the engineering career, however complex they may be, are only approximations to real situations. Thus, the accuracy of the final solution will depend on the professional's judgment.

From experience, César (2012), in the subject of Formulation and Project Management, expresses that students generally have an interest in topics related to personnel management, leadership, motivation, teamwork, being aware that they are aspects which they had not usually approached in their engineering studies, which are made up of highly technical content specific to each specialty.

The lack of preparation of the engineers in this area leads them to produce costly solutions due to the time taken to elaborate said solution and with intermediate levels of efficiency and innovation. Finally, we must not leave aside the basis of an engineer, which corresponds to optimization and control, innovation and critical thinking.

Technologies of Informatics and Communication. The new demands of society require engineers with greater technological connotation to improve productivity and global competitiveness. Currently, engineering students only use ICT as a medium that provides the execution of university tasks, delimiting a basic instruction of tools that allow them to fulfill these tasks. To meet the challenges of the profession, engineering provides software specialized either to create a product or to simulate processes. The correct operation of these requires an engineer who possesses a solid and versatile knowledge.

Next, the opinion of the students of degree in engineering on the degree of development of subjects related to the technology of the computer science and the communication in the classroom is presented.

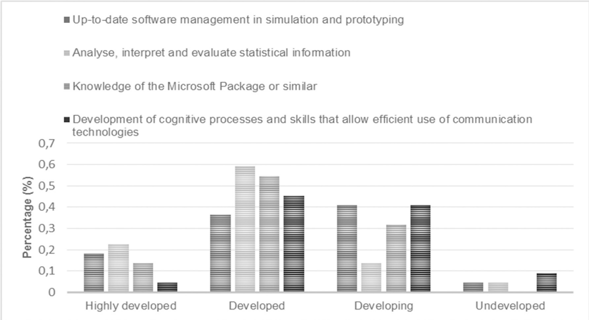

Fig. 5. Level of development of topics related to computer technology and communication

From Fig. 5 we can conclude that the handling of the Microsoft package and similar in the classroom is present in both universities but at different levels of development so more work should be done to polish this much needed knowledge in the professional world. On the other hand, topics such as software management for simulation and prototyping, the ability to process information and formulate results through analytical and graphical methods and the development of a cognitive process and capabilities that allows the effective use of technologies of communication in the classroom have some relevance but are not optimally developed despite being indispensable in the engineering world.

The training modalities supported by ICTs lead to new conceptions of the teaching-learning process that emphasize the active involvement of the student in the learning process; Attention to emotional and intellectual skills at different levels; The preparation of young people to take responsibility in a world in rapid and constant change; The flexibility of students to enter a world of work that will require training throughout their lives; And the skills required for this continuous learning process.

Thus, training engineers with computer and communication technology skills implies obtaining engineering results with greater precision and speed, as well as providing the engineer with the tasks of design, optimization, simulation, data processing, multidisciplinary work and Communication of results.

Soft Skills. Although it is essential for an engineer to acquire knowledge and develop engineering skills to be considered as such, this will allow him to differentiate himself from other professionals and have the ability to perform specific tasks of the profession, the development of soft skills will allow them to fully exploit their skills by communicating with their peers, people in general, and of course, within multidisciplinary working groups, which prevail today due to the increasing complexity of the problems to be solved.

The following is the opinion of engineering students on the degree of development of topics related to soft skills in the classroom.

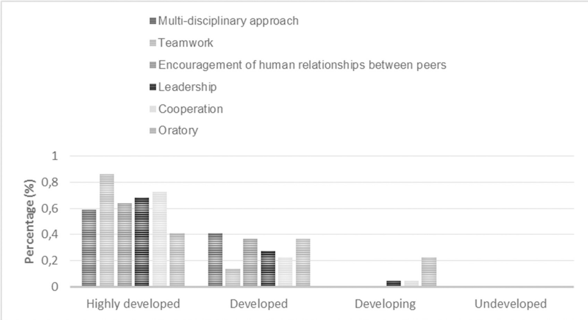

Fig. 6. Level of development of subjects related to the soft skills in the education of degree in engineering

From Fig. 6, it can be concluded that the development of themes related to soft skills, such as the promotion of multidisciplinary and team work, the promotion of human relations in the work environment, leadership, cooperation between pairs and oratory are on average highly developed in the universities, so we must continue working in this way and always aim for innovation and the improvement of methodologies and technology for this purpose.

In this way, it is important to emphasize that human relations are the support for any team work to be efficient and enjoyable and this paper emphasizes teamwork and multidisciplinary work because it is part of the reality with which students will have to deal in their professional, academic and daily life.

In turn, knowing how to work as a team from respect and cooperation, having good communication with peers and assuming leadership tasks will allow the professional to excel and exalt their possibilities to grow in their profession and will be an indispensable and unique human resource in the field in which he exercises.

Morals and Ethics. From the book Biblical Bases of Ethics, James (2003), we can say that morality has to do with personal convictions, which are formed from the influence of the society in which we are born, of our culture. On the other hand, ethics is the science of morality, a normative science, that is, it determines the values and norms that regulate the behavior of human beings in a society, it is part of the culture of a community.

From the definitions of ethics and morality, it is possible to emphasize the importance of training our engineers in this field not only to guide their individual actions towards what is considered the correct way to act in a space and a certain time but also to lead engineering and the international community towards a proactive and responsible development that ensures the rights of people and life on Earth.

On the other hand, the continuous advance of technology not guided by ethics and universal morality, especially the war and mass destruction that are the product of the actions of governments, universities and companies that promote this item, could endanger life on Earth and even the physical permanence of the planet.

The following is the opinion of students of engineering degree on the degree of development of issues related to ethics and morals in the classroom.

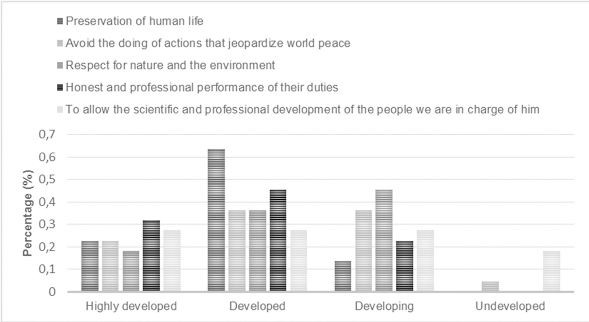

Fig. 7. Level of development of topics related to ethics and morals in education of degree in engineering

From Fig. 7 we can conclude that the degree of development of the proposed topics related to ethics and morals in engineering, such as the preservation of human life, the development of actions that endanger world peace, respect for nature and the environment, the fact of carrying out the specific activities of our work in an honest and professional manner and allowing the scientific and professional development of peers and subordinates, is quite varied and it is yet to be decided on how these topics should be included in the training of students because of the importance they have on negative consequences of interest, mainly global and in many cases also irreparable.

The fact that we have developed state-of-the-art technology and achieved great progress as a society in terms of quality of life, knowledge and technology, will not protect us from parallel actions that lead to our own destruction, promoted mainly by the use of deadly weapons in warlike conflicts where the lives of millions of people depend on the temperament and the decisions of a person or group of people and the pollution of the environment that produces a gradual but powerful damage over time.

In this way, educating our future engineers in the field of ethics and morals will allow the student to form a collective conscience about good and evil that possibly influences their decision to develop technology for destructive and irresponsible ends and thus preserve life and world security.

3 Conclusion

University is the educational institution that first receives the future professionals and it is there that they form their first conception of the career and acquire the knowledge that will allow them to have a good performance as professionals in the future. With this work we want to emphasize that the academic training of an engineer in university must be compatible with the professional training that is demanded, and that these demands are not only imposed by the company or institution in which they are but also by society itself.

Thus, it is important to train our engineers from the demands and challenges of our world today, promoting the training of professionals nourished in matters related to their profession proper but also in matters related to society, economy, human relations, technological advances, respect for the environment and ethical and morally correct actions to achieve an engineer who thinks globally, acts with a view towards the future and solves problems considering the challenges that the technological change poses to the sustainability and the global security.

From this point of view, worthy is the engineer who can assume a leadership role in the field in which he performs, being aware that his role does not only cover purely numerical and design issues, but rather responds to development and refine technology from a global conception of problems by integrating social, economic, environmental, ethical and moral variables to achieve technical solutions that are viable, innovative, sustainable and effective, with available resources.

In conclusion, university managers and professors are urged to discuss whether or not it is appropriate to add subjects to the curricular space related to economics, society, human relations, environment, information and communication technology, ethics and moral while still holding in account the purpose of university as such.

We are going through an important paradigm shift on the knowledge and skills necessary and sufficient to form an engineer but we must take into account that mono-disciplinary and purely technical training is not enough to perform engineering functions in real life, so it will be necessary to discuss the problematic and allow the entry of new ideas, even if they are revolutionary, for the improvement of academic education and the benefit that this would imply for the student and society as a whole.

Thus, from this work, universities around the world will be able to reflect on the contents and the methods from which they are forming their students and if these are really in accordance with the needs and facilities of the current world.

The next step is to work with managers, professors and students from voluntary universities to discuss the challenges mentioned in the paper and modify the curricula and teaching methods, then analyze the results and continue the process with the aim of improving engineering education, but according to the needs of students and the community.

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MCDM for Engineering Education: Literature Review and Research Issues

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Abstract. The Multi-Criteria Decision Making (MCDM) methodology had been widely applied and accepted in businesses, industries and manufacturing sectors. However, there is a limitation of resources available on discussing the way of MCDM may applied in engineering education decision problems within university setting. The current economic crisis as well as the changes in the way Ministry of Higher Education providing funding to higher education institution had created a major shift in emphasis. Both public and private higher education institutions are facing increasing cost and declining revenue streams. The purpose of this paper is to review the literature which focused in seven majors engineering education decision problems: resources allocation, performance measurement, budgeting, scheduling, planning, obtaining resources, and evaluation. The paper carried out review of articles in international scientific journals and well known international conferences related to MCDM applications published within 2000 and 2016 inclusive. Related articles are reviewed and analyzed for the types of decision problems that were paid most attention to, MCDM approaches adopted, and inadequacies of those approaches. Some improvements and possible future works are recommended based on those inadequacies. The reviewed result will create an interest to university management as it is presented in an effective way to academic process improvement, resources allocation and achieving greater satisfaction among students.

Keywords: Engineering education · Multi-criteria decision making · Decision analysis

1 Introduction

Engineering education is one of the components in higher education and its quality tends to be the assurance of the level of educational quality at Higher Education Institution (HEI). This occurrence has led to high demand of engineers with excellent abilities and skills in applying their knowledge creatively and innovatively to solve real life problems. Hence, it is a need for engineering education institution to produce graduates who will fulfil the high standard requirement as needed by industry,

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government and other sectors of society. However, the quality of engineering education faces the challenges from persistent worldwide economic with major restructuring of business and industry and advent of the information technology era that will affect the culture and method of engineering education [1, 2]. These phenomena causing universities have to manage their system optimally and keep improving their performance so that enough funding can be raised to cover necessary expenses [3].

Traditional activities such as teaching, research and service were increasing committed to the need of society [4] and universities have been assuming play a crucial responsibilities within development of economy [5]. Furthermore, there have been major transformations in the legal and institutional setting of most universities [6]. As a result of these developments, there was an opportunity and challenge for aligning each institution of higher engineering education (IHEE) system to activity of its faculty members with its objectives and strategic plans. Therefore, IHEE needs to manage each of them through process which include resources allocation, performance measurement, budgeting, scheduling, obtaining resources, and evaluation, so that the performance in term of teaching and research can be improved. Aligning those academic administrations with policies and objectives which comprised numerous conflicting interest groups involve decision making. Management science concepts and techniques have long been applied to academic administration.

MCDM was introduced in the early 1970's. MCDM methodological had been adopted by most researchers and academician for dealing with complex academic administration problems. In general, MCDM is a modeling and methodological tool which used by most universities for dealing with the real situation involved handling multiple conflicting objectives simultaneously.

In 1996, Mustafa and Goh [7] reported that 62 higher education administrations had proposed to apply the MCDM techniques in university settings. Within the MCDM, Multiple-Objective Decision Making (MODM) techniques (such as Goal Programming) were 60% more prevalent to be applied as compare to Multi-Attributes Decision Making (MADM) techniques (such as Analytic Hierarchy Process). However, the report did not emphasize on the application of other quantitative techniques such as mathematical modeling in operation research. Quantitative analysis is crucial to decision makers especially if the decision makers have little experience with similar problems, or problems are very sophisticated [8]. Although Ho *et al*. [9] had considered quantitative techniques in their paper; they did not focus on other applications of MCDM techniques in academic administration such as scheduling, planning, obtaining resources, evaluation and planning.

In addition, White [10] had classified that the primary purpose of application of management science techniques in academic administration are based on resource allocation, budgeting, scheduling, planning, obtaining resource, performance measure and evaluation. Mardani *et al*. [11] also reviewed a total of 393 articles related to MCDM and its applications published from 2000 to 2014. However, there is less specific attention was paid on the application of MCDM in engineering education.

Hence, this paper focused on providing an overview of the published application of MCDM methodology in IHEE. Once completion of this review, which MCDM techniques and management process were prevalent applied in engineering education and inadequacies of approaches adopted by previous researchers could be known.

This report was organized as follows. Section 2 explained which database and what searching criteria were used for finding the relevant journal articles. Section 3 described the categories of MCDM techniques including MODM and MADM, and distinguished their differences. Section 4 involved analyses the result of the finding by figuring out the trend of researchers, discussed some improvements on approach proposed by previous researchers and possible future work. Section 5 concluded the paper.

2 Review Methodology

The present study was aimed to investigate the application of MCDM approach to IHEE management process through reviewing previous work done by researchers and classification of international journal articles within 2000 and 2016 inclusive. The main purpose for sorting out articles within this period was that most of the studies relevant to IHEE using MCDM had gained much attention from researchers after some researchers [7, 8] had reported a detail of its advantages.

The review methodology of this paper was carried out through the used of internet and database to analyse the different aspect of topic related to MCDM application. Initially, the application of MCDM techniques to higher engineering education management process was seek through a literature review and classification of international journal articles from 2000 to 2016 inclusive. The relevancy of the journal papers found in databases were filtered based on title, abstract and keyword fields. In addition to the query of "higher engineering education", the keywords such as resources allocation, performance measurement; budgeting, scheduling, planning, obtaining resources; evaluation; MCDM; MODM; MADM; AHP; operation research and mathematical modeling were searched simultaneously.

After topic filtering, twenty-two papers were selected and studied to understand various research issues and techniques of MCDM being explored by researchers applying MCDM approach to solve the decision problem found in the higher engineering educational settings. On the other hand, there were many limitations to the search methodology. One important limitation was the availability of the papers to the authors. Primary databases searched for paper were Emerald, Elsevier, IEEE and Springer publishing groups. Many papers were reviewed from cross references because it contained the required information.

3 Multiple Criteria Decision Making (MCDM)

MCDM was one of the most widely applied decision methodologies in engineering, management science, and business. The MCDM approaches have gained much attention from practitioners and researchers, particularly among academia due to its ability to improve the quality of decisions by creating the policy development more effective, rational and explicit. A large number of approaches and techniques have been introduced in this area of study. Previous literature consisted of numbers of classification of MCDM tools with fuzzy theory sets [11]. The developed of MCDM approaches was mostly based on various real academia problems that require the consideration of multiple criteria.

Generally, MCDM techniques can be divided into two categories which are Multiple Objective Decision Making (MODM) and Multiple Attribute Decision Making (MADM). MODM techniques are the extension of linear programming. Linear programming model was defined as involvement of linear expressions in single objective function and constraints, where decision variables are continuous [12]. However, MODM techniques involved multi-objective functions that were incorporated into the model simultaneously. While, MADM techniques aimed at selecting from a population of feasible alternatives which characterized by multiple attributes. Both techniques were widely being adopted compared to other MCDM techniques as they possess unique advantages.

3.1 Multiple Objective Decision Making (MODM)

Goal Programming (GP) invented by Charnes and Cooper [13] is the most highly developed and tested techniques of linear programming, particularly a programmatic method for MODM. The concept of this technique has similarity to the linear programming model except it involves the incorporated of all goals (objective) into a single model. The goals as well as their priority level are identified by the decision makers.

Basically, the target of the most important goal had to be attained to the fullest event before target of the second goal was considered in solution generating process. This procedure was followed within the given system constraints until the targets of all goals are fulfilled to the fullest extent. The other approach of MODM methods was the vector optimization algorithm. These methods required the generation of the entire efficient solution of a set of a multiple objective problems. However, this method had been criticized for their computation burden in generating the entire efficient set in selecting a solution from an infinite number of alternatives [7].

3.2 Multiple Attribute Decision Making (MADM)

The multiple attribute utility theory (MAUT), outranking methods, and Analytic Hierarchy Process (AHP) are the widely methods of MADM. However, the AHP method developed by Saaty [14] was found to be the most prevalent MADM techniques for dealing with the decision problems in higher education [7]. Saaty [14] defines AHP was a general method for structuring complex ill-structured multi-attribute problems and comprised of three main operations including hierarchy construction, priority analysis and consistency verification.

Basically, the approaches of the AHP methods can be characterized by the following procedure:

- Complex multiple criteria decision problems break down into its components parts where every possible attributes are arranged into multiple hierarchical levels.
- Compare each component in the same level in pairwise fashion based on decision maker's own experience and judgment.

However, some degree of inconsistencies may be occurred since the comparisons were carried out through personal or subjective judgments. The final operation named consistency verification should be carried out to ensure the judgments were consistent. This verification was regarded as one of the most advantages of the AHP as the degree of consistency was measured among the pairwise comparison by computing consistency ratio [8]. Lastly, the judgments can then be synthesized to figure out the priority ranking of each criterion and its attributes.

AHP approach thereby providing a feedback mechanism for the decision makers to review and revise their judgments. In some multiple criteria decision problems like resource allocation in higher education, the decision makers would like to know how much should be allocated to which area (e.g., number of administrative staff employed) [7]. For this reason, the GP can be incorporated with the AHP because the decision variables are used to determine the amount of allocation. It can definitely provide more and useful information for the decision makers. Based on the above analysis, it was believed that it must be beneficial to the decision making process if the AHP and the GP are integrated together.

4 Result Analysis

There are 22 journal articles which appeared in the period 2000 to 2016 studying the resource allocation, performance measurement, budgeting, scheduling, planning, obtaining resources and evaluation in higher engineering education setting. In IHEE, the involved resources were basically students, faculties, staffs, facilities, equipment, financial, scheduling time and some external assistance form government, community or industries.

In this context, resource allocation can be defined as levels of certain resources to be determined and allocated among competing members or activities. Budgeting is concerned on dealing with financial allocation and scheduling related to allocation of time slot for course, examination and classroom. Performance measure was referred to evaluate and analysis of efficiency and/or effectiveness used of certain resources. Whilst, planning concerns on the process of preparing a set of information based on alternative in managing policy formation or any relevant administrative action. Furthermore, obtaining resources were related to availability levels of certain resources and effects of certain actions was performed on its. Lastly, the evaluation may refer to the comparative analysis on efficiency or performance of the available resources. Relevant journal articles were classified according to the above mentioned categories in IHEE administration.

The classification of these journal articles and techniques used in each decision problems are summarized in Table 1. Three issues related to these relevant journal articles are examined including:

(1) What kind of decision problems was paid most attention to?
(2) What types of MCDM techniques commonly applied and implemented?
(3) What are the possible future works after a detailed analyze of the approaches?

Table 1. Summary techniques used in focus major higher education decision problems

Decision problem	Researches	MCDM techniques used
Resources allocation	[15]	MCDM
	[16]	Qualitative
	[17]	MCDM
	[18]	Qualitative
Performance measurement	[19]	Quantitative
	[20]	Quantitative
	[21]	Qualitative
	[22]	Quantitative
	[23]	Qualitative
	[24]	Qualitative
Budgeting	[25]	MCDM
Scheduling	[26]	MCDM
Planning	[27]	MCDM
	[28]	MCDM
	[29]	Quantitative
Obtaining resources	[30]	MCDM
	[31]	Quantitative
	[32]	Quantitative
Evaluation	[33]	Quantitative
	[34]	Quantitative
	[35]	Quantitative
	[6]	MCDM

4.1 Higher Education Decision Problems

Regarding the various decision problems in higher educational setting, performance measure was the most commonly studied as shown in Table 2. Most of the subjects of performance measure conducted by researcher were generally in performance of IHEE [21, 22], and faculty or department members or students [19, 22, 23].

Table 2. Number of articles in each higher education decision problems

Decision problem	Number of articles	%
Resources allocation	4	18
Performance measurement	6	27
Budgeting	1	5
Scheduling	1	5
Planning	3	14
Obtaining resources	3	14
Evaluation	4	18

The number of articles studying evaluation and resources were both four articles respectively. Among the five articles related to evaluation, the focus from most of researchers [6, 33, 35] was mainly on developing evaluation model in analyzing the decision problems. For example, Costa *et al*. [6] had proposed a new faculty evaluation model that addressed the whole range of academic activities and adopted by engineering school of the Technical University of Lisbon. Other researchers [34] studied on the comprehensive evaluation of students' vocational ability based on AHP approach.

For the resource allocation, the focused of the articles was mainly on allocating resources to students or faculty members. Datta *et al.* [15] had applied the MCDM approach with the used of comprise ranking method in allocating an appropriate supervisor to students. While, Rouyendegh *et al.* [17] suggested MCDM approach to solve decision problem by allocating good working area for industrial engineering students.

It was then followed by the three decision problems regarding planning and obtaining resources respectively that had conducted by researchers. Among the three articles related to obtaining resources, the focuses of researchers were diverse. Banerjee *et al*. [31] studied the use of MCDM approach to solve the decision problems involvement recruitment of faculty members in engineering organization. On the other hand, Isik *et al*. [32] used the AHP approach to obtain the learning management system that best suited students. Focus areas involving planning decision problem conducted by researchers also diverse. Lopez *et al.* [22] conducted a study on the web based learning object selection in engineering education using AHP process. While Erkan *et al.* [28] were conducted a study on determining industrial engineering curriculum change parameters for Bachelor's Degree students in Turkey by MCDM.

Comparatively, decision problems involved budgeting and scheduling had attracted less attention. Each of these categories only consists of one researcher carry on this study. Only Awingo [25] was focused on budget decision problem and developed a goal programming model for budgeting in IHEE. While, for scheduling problem, Parthiban *et al.* [26] solved assignment problem for faculty course by decision making models.

Unlike the findings of Mustafa and Goh [7], performance measurement was paid most attention rather than resources allocation. This occurrence was due to funds provided to most IHEE was performance related. Therefore, it was crucial for decision makers to conduct performance measure including academic activities such as teaching and research, so that continuous improvement on quality of engineering education can be proceed based on bench-marking results. However, performance of all individual members from IHEE was highly related to available resources allocated and budget to them. Thereby, it was crucial to study this issue in the immediate future.

4.2 Techniques Used

Techniques used to solve those problems as stated in Table 1 can be classified into three categories: MCDM, quantitative and qualitative. As shown in Table 3, the quantitative approach was mostly adopted by researchers as there are nine articles applying this approach, which is slightly more than application of MCDM approach, that is eight articles.

On the other hand, qualitative approach had attracted much less attention and applied to the resource allocation [16, 18] and performance measurement [23, 24] decision problem in IHEE setting. It was interesting to find that most of the researchers will apply quantitative and qualitative approach in solving problem regarding performance measure in university rather than adopting MCDM as suggested by Ho *et al*. [9]. However, this finding was similar with Ho and his colleagues [9] that MCDM approach techniques can be applied to resources allocation [15, 17], budgeting [25] and scheduling [26]. Furthermore, both qualitative and quantitative had gained much attention than MCDM techniques, 23%, 41% and 36% respectively. Most of researchers such as Ho and his colleagues [9] and Janis [36] claimed that the MCDM was a practical and applicable technique coincided with real world problem as decision problem normally comprised of multiple criteria rather than single objective. It was, therefore, worth investigating the application of MCDM techniques to IHEE decision problems in the immediate future.

Table 3. Numbers of articles in each technique

Techniques/Tools	Number of articles	%
Qualitative	5	23
Quantitative	9	41
MCDM	8	36

4.3 Possible Future Work

After the detailed description of the approaches in the previous section, two major possible future research areas can be recommended. First, it was noticed that nearly most of the journal articles studied performance measurement. Only a few journal articles, however, investigated resource allocation. Resource allocation was definitely a dominant attribute of performance. A system's performance can be enhanced by providing that sufficient resource is allocated to it. Due to gradual cuts in higher education budgeting, resource allocation should be optimized so that the performance of a university can be at least maintained or even superior to its competitors. Furthermore, resource assignment is closely related to budgeting problems. In present study, it was found that only one reported budget decision problem using MCDM by IHEE. Thus, developing MCDM models for usage at solving budget decision problems in IHEE where future work is critically needed.

Second, quantitative, particularly AHP approach [18–20, 27, 28, 31, 33, 34] were found to be the most prevalent techniques in dealing the decision problem with multiple criteria. It had applied to all major decision problems. This situation was due to most judgment made by decision maker is determined subjectively and may induce some inconsistencies. This condition had encouraged most of the researchers to adopt AHP approaches since it involves the consistency test to examine whether the judgment made is consistent. However, this approach may not suitable for other decision problems, particularly for evaluating performance of each criterion. It was suggested to incorporate the GP to formulate the goal equation and objective function once consistency test is satisfied. Since some knowledge-based agents are hybridized in the original GP technique, we called this as knowledge-based goal programming (KBGP) technique which normally used to tackle the resource allocation problem or model [9]. For example, since Erkan *et al*. [28] found that there was a gap of reaching a uniform group decision in curriculum design and planning, they proposed MCDM approach that identifies relevant and essential criteria in changing curriculum parameters. They had adopted AHP to prioritize the criteria. The criteria comprised of two alternatives of curriculum. In each criterion, there were multiple attributes. The higher the scores, the higher the possibility of the curriculum to be adopted. Undoubtedly, their approach can be well applied to plan and develop the curriculum. However, this approach may not suitable for other decision problems, particularly for evaluating performance of each criterion.

4.4 Implementation of MCDM Techniques

Recently, MCDM has gradually made some significant impact on IHEE administration based on gathered articles. Regarding to this evidence, most of studies or gathered articles (approximately 60%) indicated post implementation compared than a proposed work or pilot implementation. The implementation rate was relatively high may due to MCDM approach allow a greater improvement for decision makers in obtaining the best solutions in solving complex problems involving several factors. Furthermore, a hybrid MCDM approach have gained much attention from various researchers [16, 30], which allow greatest improvement on the part of the decision maker of IHEE in the modeling stages. Thereby, the MCDM would become easier to be used and implemented.

The reviewed of work relevant application of MCDM in IHEE is aimed to encourages readers who involved in the IHEE administration to apply MCDM approach in decision making process, particularly solving complex problem or obtaining the best alternatives. Applying MCDM methodological would allow modelers or decision makers to have a systematic and efficient in searching for optimum solution by considering all the objectives or factors in the problems modeled.

5 Conclusion

This paper mainly reviewed the application of the MCDM techniques to seven major higher engineering education decision problems, namely resource allocation, performance measurement, budgeting, scheduling, planning, obtaining resources and evaluation. It was found that nine out of 20 journal articles collected in the 2000 to 2016 studied performance measurement. The previous researchers preferred measuring performance of universities, department or faculty members. Resource allocation also gained much attention from researchers as most of the universities currently facing gradual decrease in higher engineering education funding. This study has some major limitation that can be considered as recommendations for future work. First, this review paper is focused on the use of MCDM techniques. Articles published in earlier than 2000 and late 2016, if any, are not included in present study due to limited reporting time. It was suggested that a future review can be expanded further in decision making scope. Furthermore, there are also some qualities papers on MCDM application may have been left out of this review due to limitation in the search methodology. The data collected is excluding textbooks, doctoral and master dissertations, PhD thesis and unpublished articles in the MCDM issues. Thereby, data collected from these scholarly journals and obtained results can be compared with this paper. However, authors believe that there is comprehensively review on papers from high reputable publishers although some of relevant outlets may have remained outside the scope of this study. Thereby, future studies can review those articles which are not discussed in this review paper.

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Perception of Complex Engineering Problem Solving Among Engineering Educators

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Abstract. According to the Washington Accord, skills to solve complex problems in engineering are important in the curriculum of engineering education. To fulfill the accreditation exercise, engineering educators must be able to design complex engineering problems to assess the learning of this important skill. Therefore, this research was conducted to explore what do engineering educators perceived as complex engineering problems and how did they design these problems in order to foster the skills among their students. A focus group discussion was conducted among 12 engineering educators. The audio recording was transcribed and analysed qualitatively. The result shows that only one engineering educator understands complex engineering problems and most of the attributes. The other were not able to tell more than three of the complex engineering problem attributes. As a conclusion, training on the attributes of complex engineering problems is needed to ensure that the teaching and learning of engineering programmes fulfill the accreditation criteria.

Keywords: Complex engineering problem · Engineering problem solving · Accreditation

1 Introduction

The grand challenges of the 21st century require human race to solve problems and face uncertainties that we have never faced before. According to World Economic Forum (2016), the top most important skill for the fourth industrial revolution by 2020 is Complex Problem Solving. Therefore, it is ever more demanding to have competent problem solving skills to survive in this century. Students must equip themselves with abilities to think critically, creatively and solve problems at all level of education especially at the tertiary level. Moreover, engineering students are required to have the skills in knowledge acquisition, synthesis, reasoning, problem analysis, operation and evaluation (Funke and Frensch 2007). Hence, engineering students should be able to deal with and solve complex problems.

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A study conducted through the collaboration of three UK universities, the Institute of Engineering and Technology (IET) and the Higher Education Funding Council of England (HEFCE) summed up that 77% of employers request graduates who is able to self-learn and 74% of employer needed problem solvers. A working group lead by Sir David Brown (ex-chairman of Motorola and IET president) that comprised of a balanced membership of academics and industries discovered that most employees search for graduates with key skills. They desire for these skills to be adapted into the engineering degree courses and assessments. Rather than focusing on the cognitive knowledge possessed by the students, employees show distress over the lack of key skills of the graduates. The highest of all these skills are problem solving (IET 2008).

Doubts are expressed on the current engineering education program in which some theories thought in universities are never translated into reality. Furthermore, the current grading system is often a poor indicator of a graduate's abilities. There are various comments on how well lecturers deliver the engineering courses and help students to develop these skills. In universities, project works are viewed as important in developing problem solving skills. However, in most cases, the projects given were limited and lack real issues of the working environment. Even though project work was universally seen as important, it needed more relevance then the usual determined structural problems. Another criticism within the assessment of universities is the stress put upon students on rote learning and memory. Students must equip themselves with abilities to think critically, creatively and solve problems at all level of education especially at the tertiary level. Moreover, engineering students are required to have the skills in knowledge acquisition, synthesis, reasoning, problem analysis, operation and evaluation. Hence, engineering students should be able to deal with and solve complex problems. The worth of an engineer is not just determined just because one does not remember 100 equations (Spinks et al. 2006).

Problems that are often encountered in engineering education programs are well structured. One of its characteristics is that it can be solved by applying an ideal solution method. The problems only apply a limited number of common rules that are organized predictively (Jonassen 1997). When facing with a well-structured problem, students will only need to translate the unknown relationships into equations, solve the equations and validate that the values satisfy the problem. This is a linear process in which students memorize the procedures and habituate it. This process puts and emphasis on getting answers over making meaning. In the end, it develops students who are contented with superficial engineering knowledge rather than understanding it profoundly.

In reality, engineers function as problem solvers. They are employed, retained and salaried to solve problems, especially complex problems. Therefore, it is vital for engineering students to be exposed to ill-structured (workplace) problems. Workplace problems are not parallel to problems often given to students in classrooms. The nature of workplace problems is commonly complex and ill-defined. This happens because of conflicting goals, multiple methods in solving the problem, unexpected problems or solutions, and various form of problem representation. Consequently, the ability to solve common classroom problems does not actually ensure the success of a student in solving actual workplace problems (Jonassen et al. 2006).

2 Problem Solving

Problem solving involves higher-order skills and is among the most authentic, useful, and crucial skills that learners can develop (Jonassen 1997). With this regards, Mina et al. (2003) proposed to look at the problem from the lens of John Dewey. They found that the objective of engineering education program is parallel to John Dewey's own educational understanding. The context "philosophy of inquiry" Dewey (1938) used is similar to engineering education programs' "problem solving skills". From Mina's observations through John Dewey's perspective, it can be concluded that in the context of problem solving, today's bloated education system does not promote nor produce problem solvers. In fact, due to the lack of flexibility and emphasis on "discovery aspects of education", development of problem solving skills may also be inhibited. The adverse effects of current education system can be observed in students' behaviour towards education which includes short retention spans and lack of determination in improving knowledge.

According to contemporary learning theories, problem solving is the pinnacle of a practice (Syed et al. 2016). Current concepts of student centred learning, such as open-ended learning (Hannafin et al. 1994; Land and Hannafin 1996), goal-based scenarios (Schank et al. 1993), and problem-based learning (Barrows and Tamblyn 1980; Barrows 1986; Woods 2000; Tan 2004) concentrate on problem solving outcomes. These concepts tend to provide students with instructional strategies which include authentic cases, simulations, modelling, coaching, and scaffolding. The instructional strategies function as a support to the problem solving outcomes but insufficiently analyse the nature of the problems.

According to Jonassen and Hernandez-Serrano (2002), for students to solve ill-structured for students to solve ill-structured problems, they must have sufficient conceptual framework. Ill-structured problems are defined ambiguously, with indistinct aims and constraints. The problems possess a multitude of solutions and solution paths with no distinct consensus on the proper solution and no obvious method of defining proper actions or connections among principles that are used. In order to evaluate ill-structured problems, students will have to observe the problems thoroughly from across multiple criteria. Finding the solutions to the problems require learners to make decisions and express and defend their opinions. Educators once believed that the knowledge to solve well-structured problems can be transferred and used in solving ill-structured problems. Yet, as some recent research explicitly shown, knowledge to solve well-structured problems is not readily transferrable to solve ill-structured problems. In other words, the ability to solve well-structured problems, which is developed in the current engineering courses, would not enable graduates to solve complex, ill-structured workplace problems.

In order to produce engineers with the ability to solve complex engineering problems, engineering educators must be able to design complex engineering problems to assess the acquisition of the skill. This means that engineering educators must know the attributes of complex engineering problems.

According to the Washington Accord (IEA 2015), complex engineering problems are problems that:

a. Cannot be resolved without in-depth engineering knowledge.
b. Involve wide-ranging or conflicting technical, engineering and other issues.
c. Have no obvious solution and require abstract thinking and originality in analysis to formulate suitable models.
d. Involve infrequently encountered issues.
e. Outside problems encompassed by standards and codes of practice for professional engineering.
f. Involve diverse groups of stakeholders with widely varying needs.
g. High level problems including many component parts or sub-problems.

It must be noted that a complex engineering problem as defined by (IEA 2015) must have at least the first attribute and any of the attributes from (b) to (g).

Based on a previous study (Phang et al. 2016) which assessed the complex engineering problems designed by lecturers from an engineering faculty, 58.5% of the problems were reviewed by experts as not complex engineering problems based on the attributes given by the Washington Accord (IEA 2015) as stated above. This shows that engineering lecturers may not fully understand complex engineering problems. Therefore, this study seeks to identify the understanding of engineering educators on the attributes of complex engineering problems and how they design the problems.

This is important because in the outcome-based education subscribed by the signatories of the Washington Accord, constructive alignment is particularly important. In the constructive alignment, the learning outcomes, teaching and learning activities and the assessment must be aligned (Biggs 2003). In another words, if we claimed that an engineering program produces engineering graduates with the skills to solve complex engineering problems, there must be teaching and learning activities that support it and the assessment must be able to show the performance of the graduates in the skills. Hence, the lecturers'understanding of complex engineering problems must be identified because they are those who are responsible of teaching the skills and designing assessment methods to determine the student achievement in the skills.

3 Research Method

In order to explore the lecturers' understanding of complex engineering problems, qualitative inquiry was conducted. Creswell (1998) defined qualitative research as "an inquiry process of understanding based on distinct methodological traditions of inquiry that explore a social or human problem" (p. 15). The aim of qualitative inquiry is to explore how people make sense of their world. Some examples of research methodologies are grounded theory, ethnography, phenomenology, case study and so on. Research methods that are usually employed in collecting qualitative data are open-ended questionnaire, interview, observation, document analysis and others.

In this study, interview is a quick method to obtain rich information from respondents. It provides a two-way interaction between the researchers and the respondents (Kvale 1996). Unlike questionnaire and test, interview allows the respondents to ask the researcher for clarification when they do not understand the questions or allows the researcher to explain further what information he or she intends to gather from the respondents. Furthermore, interview gives the opportunity to the researchers to probe further to gain deeper understanding from the respondents. However, interview is a time consuming method where data is collected from one respondents to another respondents.

Therefore, to reduce time for data collection, focus group interview was selected as the method for this study. A focus group interview essentially is to conduct interview with a group of respondents who have certain characteristics and focusing on one or certain issues (Anderson 1990). In this study, a focus group interview was conducted among 12 civil engineering educators who volunteered to participate in this study. The issues discussed are their understanding about complex engineering problems and how they design the problems. The researcher acted as the moderator of facilitator of the focus group interview. The researcher asked questions and moderated the session.

The respondents are from an engineering faculty of a university which were involved in another bigger study as reported in Phang et al. (2016). They may not represent all the 150 lecturers in that faculty but each department was represented by three lecturers. There are four departments in the faculty. Their teaching experience ranged from 12 to 29 years. Table 1 shows some details of the lecturers involved in this study.

Table 1. Details of the research respondents.

Respondent	Department	Years of teaching
A	Environmental Engineering	15
B	Environmental Engineering	26
C	Environmental Engineering	15
D	Geotechnic & Transportation	29
E	Geotechnic & Transportation	29
F	Geotechnic & Transportation	12
G	Hydraulics & Hydrology	28
H	Hydraulics & Hydrology	12
I	Hydraulics & Hydrology	15
J	Structures & Materials	29
K	Structures & Materials	28
L	Structures & Materials	12

They were interviewed on what they understand about complex engineering problems and how they design the problems to assess their students. The discussion was video recorded. The discussion was transcribed into texts for analysis. The data was analysed quantitatively using the method introduced by Mills and Huberman (1994). There are three stages in this data analysis method:

1. **Data reduction.** The data is reduced and organised through coding, writing summaries, discarding irrelevant data and so on. This allows the researcher to focus on the issues that he or she wants to study. However, the researcher must ensure that the original raw data is available to be referred when necessary.

2. **Data display.** To draw conclusions from the mass of data, a good display of data such as in the form of tables, charts, maps and other graphical formats will help the researcher to identify patterns and summary.
3. **Conclusion drawing/verification.** After the conclusion is made, it can then be verified by examining the conclusion to the data collected.

In this study, the transcript of the focus group interview was read through. Later, the transcript was reduced to show answers to the two issues. The responses of the respondents were quoted out and displayed in two tables. One table is for their understanding of complex engineering problems and another table is on how they design their assessment. The conclusions were checked through data and discussion among the research team members.

4 Results

Table 2 shows the result of the lecturers' understanding of complex engineering problems. The result shows that only (Respondent K) can tell most of the attributes of complex engineering problems. The attribute mentioned the most is that in-depth engineering knowledge is needed to solve the problems. Then, it was followed by the problems involve infrequently encountered issues. And finally, the problems have many sub-problems, or they are complex in nature. The rest of the 11 engineering educators can only tell no more than three attributes of complex engineering problems.

Table 2. Examples of lecturers'responses on what are complex engineering problems

Respondent	Response
D	It involves real thing and situation, not straight forward to solve it, need some skills of searching info and how to get the info, so the important thing is student must have searching skills to get something
E	No specific way to solve it. Need to use all the knowledge learns, not just from specific course to solve. Include technical, ethics, attitude and all those things to reach conclusion
H	Various problems, the problem is not straight forward to solve, if we want to solve it we need to have a fundamental and deeper knowledge
I	Integrated task, multi solution and complex activities, it must a real problem and engineering problem
K	No single solution, include conflicting technical, depth analysis is important as complex problem requires abstract thinking, depth of knowledge, unfamiliar issues and use other codes

With minimal understanding of the attributes of complex engineering problems, some engineering educators cannot explain how they are able to design complex engineering problems. Table 3 shows their responses on how they design complex engineering problems to assess their students.

Table 3. Lecturers'responses on how they design complex engineering problems

Respondent	Response
C	The questions are integrations from several topics
D	It is related to the syllabus; we never teach before but provide hand out or give short briefing about the project. The students need to find on their own. Go for interview and learn how to get the information from other people. The students are out of the comfort zone
E	I did like C. I related all the other topics while teaching highway subject
G	So far, it is difficult to design a complex problem in examination paper for Year 1 because the lessons are very fundamental and not specific
H	I design complex problem in case study because it is opened. Students create the problems, think independently, they measure and find their own solution. They need to identify the problem first
I	The task is more on complex activities, consortium to solve the problem, must integrate to find the result and involve more integration activities
K	Each of the level has their own complex problem. Final exam is not suitable to design complex problem because complex problem consume times and lots of discussion

Most of them refer to the learning outcomes when designing complex engineering problems because they believed that complex engineering problems must involve in-depth engineering knowledge and sometimes, knowledge out of the syllabus. They also believe that examination is not suitable to test complex engineering problem solving skills. It must involve activities, especially integrated activities and discussions, such as case study.

However, based on a previous study (Phang et al. 2016) among the lecturers from this faculty, there are 14 complex engineering problems found in the final examinations (see Table 4) though most of the complex engineering problems can be found in projects. Figure 1 shows an example of a complex engineering problem designed by a lecturer for a final examination.

Table 4. Types and number of assessment tasks that are complex engineering problems

Types of assessment task	No. of task
Assignment	8
Project	17
Test	2
Final Exam	14

SECTION A

Q1. Sungai Melana is a small river flowing through several residential areas in Skudai, Johor Bahru. You are a consultant appointed to propose a **river restoration action plan** for a part of Sungai Melana beginning from the upstream at Taman Teratai until the midstream at Taman Universiti. Your proposal should include action plans to accomplish the following objectives :

a) Improving the water quality of Sungai Melana to Class II and III
b) Prevention of direct solid waste discharge into the river system
c) Creating suitable habitats for the propogation aquatic life
d) Adding property and aesthetic value to residents living along the river

Your answers should be written to address each of the above items separately.

(20 marks)

Fig. 1. An example of a final examination that is marked as a complex engineering problem

5 Discussion

From the results, the engineering lecturers have the basic understanding of complex engineering problems as outlined by the Washington Accord (IEA 2015) that the problems must involve the application of in-depth engineering knowledge. Based on a previous study (Phang et al. 2016), the complex engineering problem attributes that were found in the problems designed by the lecturers from this faculty are the first three attributes as listed in the Introduction of this paper which are:

a. Cannot be resolved without in-depth engineering knowledge.
b. Involve wide-ranging or conflicting technical, engineering and other issues.
c. Have no obvious solution and require abstract thinking and originality in analysis to formulate suitable models.

Less than 6 problems were found to have the following attributes of complex engineering problem:

d. Involve infrequently encountered issues.
e. Outside problems encompassed by standards and codes of practice for professional engineering.
f. Involve diverse groups of stakeholders with widely varying needs.
g. High level problems including many component parts or sub-problems.

The results of this research and the previous study are aligned where only Participant K could tell the complex engineering problem attributes of (d) to (g).

6 Conclusion

Therefore, it is important for the institution to give training and educate the engineering lecturers on the attributes of complex engineering problems so that they can design engineering problems that can be used to assess complex problem solving skill in engineering. This will ensure that the engineering programme meet the accreditation requirement and produce engineers with the skill needed to meet new challenges in the future for the survival of mankind.

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A Subjective Examination of Implicit Root Stereotypes of STEM Disciplines

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Abstract. This paper addresses the concept of genderization of disciplines – in particular the disciplines of STEM (viz., Science, Technology, Engineering and Mathematics) – and, the need to de-genderize the STEM disciplines. Two examples, namely Physics and Software Engineering have been taken up for further genderization classification. It is found that various phases of both Physics and Software Engineering exhibit dominantly feminine genderizations – leading to the inference that these two disciplines are well suited to females. These observations presented in this paper would be useful in addressing issues that arise in increasing the participation of women in the STEM disciplines and other related areas.

1 Introduction

The term *gender* is used to imply a wider set of attributes than just describing the characteristics of males and females. For instance, it is well-recognized in the literature that organizations and processes also exhibit genders, gender preferences and gender biases [1, 2]. We term the process of identifying and working with the issues relating to genders of disciplines of fields and/or organizations as '*genderization of disciplines/organizations*'. For instance, a hospital exhibits typical characteristics of feminine gender, while the military is typically masculine in gender, even though people of both sexes may be working in these organisations. Some organizational processes also show gender-related influences – for example, the nursing profession and processes therein have been predominantly feminine, wherein they follow rules with local interpretations, while generic military processes and procedures follow masculine procedures of rigid adherence to definitive rules and procedures with little variations therein at all. Indeed in all Railways around the world, the drivers are trained in the same rigid manner. It is noted that the term genderization refers to the attributes of being a male or female – i.e., masculinity and femineity (and the noun variants thereof) only. We will only use the terms masculine and feminine throughout this paper and, will refrain from using the terms males and females.

The fields concerning STEM – i.e., Science, Technology, Engineering and Mathematics – contain many processes which are feminine in nature and hence we argue

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that the entire STEM is mostly feminine in nature. This has implications for women in STEM disciplines in that we postulate that STEM – taken up as a profession – is more suited to people with feminine attributes than people with masculine attributes. Indeed the term *engineering* has not helped the profession, in that engineering professions are traditionally considered the bastions of masculinity. Perhaps if we advertise the feminine nature of the fields of STEM and the processes involved in STEM disciplines, the field will become more appealing to female audience. This being the essence of this paper, we raise potential strategies to explore newer strategies for fostering STEM disciplines among all audience of students and, with more focus on female students, because the World needs science (and STEM) and science (STEM) needs women. The Noble Laureate Sir C. V. Raman once said, "*If the women are taken to science…they will achieve even what men have failed to do*". Since this new approach facilitates more women in STEM, we argue that an even gender balance could be achieved, which could result in potential enhanced approach to research in STEM disciplines.

The rest of the paper is organised as follows: Sect. 2 characterizes genderization *per se* along with a brief literature review, while Sect. 3 deals with STEM disciplines related genderization issues in depth. Section 4 describes genderization issues in a couple of disciplines of STEM. A discussion on the implications of genderization to STEM disciplines is provided in Sect. 5, followed by a brief description of the social view points on genderization and related works in Sect. 6. The conclusion summarises the paper and provides further pointers for research in this area.

2 Characterizing Genderization

A number of social scientists [1, 2] have analysed genderization in organizations and processes – generally on the basis of perception of the characteristics/attributes on genders that are nominally superficially observed by common people or as part of the so-called commonly held belief among lay people. In general, most organizations exhibit dominant characteristics that can be used to classify them as masculine, feminine, or neutral genders – see Table 1 for typical genderization characteristics. In a similar vein, organizational processes and fields of studies (i.e., disciplines) can be classified through their characteristic genders also. For example, most military and surgical processes are masculine, hospital and diplomatic service and nursing processes are feminine, and football teams, financial & educational institutional processes are neutral. We compare their genderization based on several issues such as: organizational structure, nature of processes involved, dominant communication mechanism employed, training requirement, organizational confidence in the process/procedure, adherence to rules, regulations, processes & standards, time consciousness, goal achievement and mission success. Examples of organizations are given that match these genderization characteristics in the last row of the Table 1.

Calas and Smircich [16] contend that organizational theories reflect the practical concerns of their creators, while Acker and van Houten [18] state that gender aspects of organizational research have been neglected until recently. Alvesson and Billing [19] have introduced the concept of masculinity of organizations, while Calas and Smircich [16] have observed that '*neutrality of scientific knowledge*' also exhibits gendering

Table 1. Characterization of generic organizational, process and STEM discipline genderization

Issues	Masculine	Feminine	Neutral
Organizational structure	Rigid structures	Flexible structures	Intermediate structures
Nature of processes	Well-documented	Flexible and ad hoc processes	Intermediate processes
Communication mechanism	(deeply) Hierarchical communication	Highly networked communication	Hybrid networked communication
Training mode	Regimented training	Flexible *on-need training*	Mixed training model
Organizational confidence	High organizational confidence development	Organizational confidence is relatively low	Organizational confidence is relatively medium
Adherence to rules, regulations, processes & standards	Strict adherence to rules and regulations	Flexible adherence, often customized to the environment	Both strict and customization possible
Time consciousness	Highly time-conscious activities	Comparatively less time-conscious	Intermediate importance to time
Goal achievement	Focussed in achieving finite goals at any one time	Many project goals are linked and well-established	Mixture of goals
Mission success	Success of the mission overrides the feelings of individuals	Feelings and expressions of individuals or groups override the success of mission	Both mission success and individual feelings are considered
Characteristic behaviours	Organizers and administrators	Nurturers, servers and community builders	A blend of both behavioural attributes
Example Organizations	Military, surgical procedures	Hospital, Diplomatic services (foreign affairs and trade)	Football teams, Financial Institutions, Educational Institutions
Example Disciplines of STEM	**Science:** Theoretical Physics, Physical Chemistry, Botany, etc. **Technology:** Communication Theory, **Engineering:** Verification, Validation, etc. **Mathematics:** Logic, Number Theory,	**Science:** Applied Mathematics **Technology:** Biotechnology, most aspects of Information Technology and Information Systems **Engineering:** Most Engineering disciplines, **Mathematics:** Statistics	**Science:** Library Science, Biology, Botany **Technology:** Information Management, Information Science **Engineering:** Traffic Engineering, Thermodynamics **Mathematics:** AppliedStatistics, Queuing Theory,

(*continued*)

characterizations. Manvill [15] considers genderization in religious social processes, while the work of Acker [17, 18] details the typical insignias of gendered organizations (i.e., symbols, structure, mental work, and interactions). Wilson's research [14] on gender differences in promoting success in computer science is another useful work on learning aspects and the differences between the genders. The papers in the conference stream led by Bendl and Kiall [10] and the work of Bendl [20] contain several good research works in the context of genderization, learning patterns of women in software areas and mathematics. Without appropriate female representation, the potential STEM innovations of tomorrow will be missing half of the talent of our world. [27]. Many people who performed on the Implicit Association Test (https://implicit.harvard.edu/implicit/demo) [30], which measures unconscious associations between concepts, revealed the results from hundreds of thousands of people indicate that 70% of men and women across 34 countries view science as more male than femaleand such beliefs and biases are not that uncommon.

3 Genderization Issues in Stem Disciplines

Beckwith and others [3–6] have investigated several aspects as to why women and men might interact differently with the same software and concluded that confidence plays an important role in software development[1]. We however, compare the genderization issues in STEM disciplines using the generic genderization framework that we have developed – as shown in Table 2. The identifications represent the author's own subjective view, but are derived from various published research [9]. Besides characterizing the genderization parameters in Table 2, we provide some example and typical projects also which exhibit genderization characteristics in Table 2. It is noted that the disciplines of Science and Mathematics are divided into two and examples thereof and their characterization are clearly articulated. Thus, Science-A is generic conceptualization of Physical Sciences (e.g., Mathematics, Physics, Chemistry, etc.), while Science-B is generic conceptualization of Biological Sciences (e.g., Botany, Biology, Microbiology, Biochemistry, etc.). Similarly, Mathematics-A corresponds to Statistical Mathematics, while Mathematics-B corresponds to Theoretical Mathematics.

Table 2 show the generic nature of Science – A and Science –B. However, this subjective study needs to be confirmed by conducting a structural survey on pre-conceived notions, cultural attitudes, ethical and moral issues, awareness and understanding of particular course. A few issues can be identified through the organizational structure, nature of processes, communication mechanism, training mode, etc. For each of the science subjects an example project could be identified to compare the responses and draw inferences for role of a given genderization characteristics.

[1] Indeed several types of Software Development Processes (SDPs) are described in the literature (see for example [8]).

Table 2. Generic genderization issues in STEM disciplines

Issues	Science-A (e.g.,)	Science-B (e.g.,)	Technology	Engineering	Mathematics-A (e.g.,)	Mathematics-B (e.g.,)
Organizational structure	Intermediate & medium structures	Flexible & large structures	Flexible & small structure	Intermediate & medium structures	Intermediate and medium structures	Rigid & large structures
Nature of processes	Intermediate processes	Flexible and ad hoc processes	Flexible processes	Intermediate & flexible processes	Intermediate processes	Well-Documented
Communication mechanism	Hybrid networked communication	Highly networked communication	Highly communicative	Medium communicative	Hybrid networked communication	(deeply) Hierarchical communication
Training mode	Good training is required	Flexible *on-need training*	No formal training mode, expertise is expected	Formal training is very much required	Mixed training model	Regimented training
Organizational confidence	Medium to low, due to no exposure	Organizational confidence is relatively low	Very limited as there are few past projects	Limited experience leads to limited confidence	Organizational confidence is relatively medium	High organizational confidence development
Adherence to rules, regulations, processes & standards	Both strict and customization possible	Flexible adherence, often customized to the environment	Flexibility in application of rules and regulations expected	Good adherence to rules and regulations	Both strict and customization possible	Strict adherence to rules and regulations
Time consciousness	Comparatively less time-conscious	Comparatively less time-conscious	Highly time-conscious activities	Intermediate importance to time	Intermediate importance to time	Highly time-conscious activities
Goal achievement	Mixture of goals	Many goals are linked and taking this into cognizance	Highly focussed in achieving few specific goals at any one time	Many goals are linked and taking this into cognizance	Mixture of goals	Focussed in achieving all goals at any one time
Mission success	Both mission and success and individual feelings are considered	Feelings and expressions of individuals or groups override the success of mission	Highly critical than individual feelings	Individual feelings important with limited mission success	Both mission and success and individual feelings are considered	Success of the mission overrides the feelings of individuals
Example Projects	Planned development (software upgrades)	Large scale projects (government and military ones)	Gadgets & web-based projects	Medium sized & web-based projects	Small scale government & military projects	Large scale projects (government and military ones) & scientific projects
Inference	Neutral	Masculine	Dominantly feminine	Feminine	Neutral	Dominantly Masculine

4 Example Genderization of Two Stem Disciplines

– Software Engineering & Physics

We have taken up two disciplines, namely Software Engineering (from the Engineering discipline) and Physics (from the Science discipline) to characterize and demonstrate their genderization characteristics. While Software Engineering is characterized in Table 3, Physic is characterized in Table 4. It is noted that Software Engineering is characterized by subjects/courses such as Requirements elicitation, Requirements analysis, Software design, Program design, Program development, Program testing, Program deployment and Program maintenance. The discipline of Physics is characterized by subjects/courses such as Problem formation, Problem analysis, Solution design in theory, Solution design in practice, Solution development, Solution testing, Solution analysis and Problem & solution enhancement. Various stages of both examples are genderized in each of Tables 3 and 4.

Table 3. Generic genderization issues in the various stages of software engineering

Issues	Requirements elicitation	Requirements analysis	Software design	Program design
Organizational structure	Has to be flexible	Flexible structures	Pre-defined structures	Structure defined clearly
Nature of processes	Must be consultative	Flexible and ad hoc processes	Intermediate & defined processes	Defined processes
Communication mechanism	Highly interactive	Networked & interactive communication	Hybrid networked communication	Clearly defined
Training mode	Flexible and on-need training is importance	Systematic	Systematic mixed training model	Systematic training
Organizational confidence	Developed thru' team building confidence	Developed thru' team training	Relatively medium confidence thru' teaming	Clearly high degree of confidence
Adherence to rules, regulations, processes & standards	Flexible adherence, often customized to environment	Both strict flexible adherence	Strict, but customization possible	Strict adherence to rules and procedures
Time consciousness	Highly time-sensitive activity, since customer cannot afford undue delays	Comparatively less time-conscious	Rather low importance to time	Correctness is more relevant than time
Goal achievement	Many goals which are linked	Many goals are inter-linked	All goals considered	All goals considered
Mission success	Individual feelings given importance	Feelings and expressions of group dominates	Mission success is solely considered	Mission success is solely considered
Inference	Dominantly Feminine	Feminine	Neutral	Masculine

Table 4. Generic Genderization Issues in the Various Aspects of Physics

Issues	Problem formulation	Problem analysis	Solution design (theory)	Solution design (practice)
Organizational structure	Has to be flexible	Flexible structures	Pre-defined structures	Structure defined clearly
Nature of processes	Must be consultative	Flexible and ad hoc processes	Intermediate & defined processes	Defined processes
Communication mechanism	Highly interactive	Networked & interactive communication	Hybrid networked communication	Clearly defined
Training mode	Flexible and on-need training is importance	Systematic	Systematic mixed training model	Systematic training
Organizational confidence	Developed thru' team building confidence	Developed thru' team training	Relatively medium confidence thru' teaming	Clearly high degree of confidence
Adherence to rules, regulations, processes & standards	Flexible adherence, often customized to environment	Both strict flexible adherence	Strict, but customization possible	Strict adherence to rules and procedures
Time consciousness	Highly time-sensitive activity, since customer cannot afford undue delays	Comparatively less time-conscious	Rather low importance to time	Correctness is more relevant than time
Goal achievement	Many goals which are linked	Many goals are inter-linked	All goals considered	All goals considered
Mission success	Individual feelings given importance	Feelings and expressions of group dominates	Mission success is solely considered	Mission success is solely considered
Inference	Dominantly Feminine	Feminine	Neutral	Masculine
Issues	Solution development	Solution testing	Solution analysis	Problem & solution enhancement
Organizational structure	Structure defined ahead of time	Intermediate structure	Well-defined structure	Loose structure
Nature of processes	Well-defined processes	Some processes well-defined, but not all	Well-defined and systematic	Some processes well-defined, but not all
Communication mechanism	Clearly defined	Intermediate communication structure	Clearly defined	Lacks clearly defined communi cation structure
Training mode	Systematic training	Ad hoc training (limited regularization)	Systematic training	Very limited training
Organizational confidence	High degree of confidence	Limited confidence	High degree of confidence	Low confidence
Adherence to rules, regulations, processes & standards	Well-articulated rules and procedures	Not well-articulated rules and regulations	Strict, but customization possible	Not well-articulated rules and regulations
Time consciousness	Time is important, but adherence to procedures dominates	Time to complete is more relevant than completeness	Highly time-sensitive activity, since customer cannot afford undue delays	Not time sensitive, even though it appears so
Goal achievement	Limited set of goals considered	Limited set of goals considered often	Limited set of goals and planned in advance	No pre-defined goals, but goals come in on-the-fly
Mission success	Mission success and individual feelings are both important	Mission success is more relevant, while some individual feelings considered	Mission success is critical	Individual feelings and environment driven
Inference	Neutral	Feminine	Feminine	Deeply feminine

Table 3 shows the generic gender issues in Software Design (SD) and program design (PD). However, this subjective study needs to be confirmed by conducting semi-structural interviews, survey and questionnaire in Likert scale. A few issues like the assumptions that ‘what people known about SD and PD and related issues’ could be identified. However this subjective study elicits, ‘assumptions related to requirements for SD & PD, an analysis on requirements, assumptions on Software design and Program design.

Issues	Program development	Program testing	Program deployment	Program maintenance
Organizational structure	Structure defined ahead of time	Intermediate structure	Well-defined structure	Loose structure
Nature of processes	Well-defined processes	Some processes well-defined, but not all	Well-defined and systematic	Some processes well-defined, but not all
Communication mechanism	Clearly defined	Intermediate communication structure	Clearly defined	Lacks clearly defined communication structure
Training mode	Systematic training	Ad hoc training (limited regularization)	Systematic training	Very limited training
Organizational confidence	High degree of confidence	Limited confidence	High degree of confidence	Low confidence
Adherence to rules, regulations, processes & standards	Well-articulated rules and procedures	Not well-articulated rules and regulations	Strict, but customization possible	Not well-articulated rules and regulations
Time consciousness	Time is important, but adherence to procedures dominates	Time to complete is more relevant than completeness	Highly time-sensitive activity, since customer cannot afford undue delays	Not time sensitive, even though it appears so
Goal achievement	Limited set of goals considered	Limited set of goals considered often	Limited set of goals and planned in advance	No pre-defined goals, but goals come in on-the-fly
Mission success	Mission success and individual feelings are both important	Mission success is more relevant, while some individual feelings considered	Mission success is critical	Individual feelings and environment driven
Inference	Neutral	Feminine	Feminine	Deeply feminine

In Program Development of Software Engineering it is observed through this subjective study that how the choices are made basing on the gender. However this study need to be clarified by conducting questionnaires based on ‘choice of factors for women in Software Engineering, factors that affect and factors that motivate women. To understand the generic process Likert scale (of 1-5 viz, low to high agreement) could be used to identify a given generic genderization characteristics.

Table 4 shows the issues related to Physics (as Worldwide there are less women in physics than any other STEM subjects). This subjective study provides ‘how people understand gender’, ‘their definition’ and ‘processes involved’, because nature and characteristic features of one particular subject also sometimes influences the choices people make. However, this study needs to be clarified by conducting in-depth analysis through the questionaries and interviews designed for both the genders.

5 Implications to Stem Education, Learning and Related Professions

Various STEM disciplinary processes exhibit characteristics of the three genders. Similarly, various stages of the life cycles of the fields of Software Engineering and Physics exhibit gender characteristics. The implication is that these development processes are well-suited to female/women. Unfortunately, these characteristics have rarely been brought to the attention of females, in particular to high school girls. Instead, the disciplines in STEM are treated and/or perceived very similar to other male-dominated fields (e.g., the good-old Civil Engineering and Mechanical Engineering). Only in Asian countries (e.g., India, Pakistan, and Sri Lanka) and East European countries (e.g., Poland), have STEM and STEM related disciplines seen a considerable percentage of the female population in the relevant degree programs. In the Western world, women are under-represented in most of the STEM disciplines. We hope that emphasizing the feminine aspects of STEM disciplines to high school children will help increase the female population in these programs. Culture plays a vital role in encouraging girls towards Physics. There really aren’t enough women role models in physics, and many of the great female astronomers are not often that well-known, or talked about in education.“Very often the famous names we know and read about in science are not those of women,” says Jo Dunkley a professor of physics and astrophysical sciences at Princeton University, “To get more young girls studying the subject, we must change cultural perceptions and have more visible female role models.” [28]

6 Social View Points on Genderization and Related Works

Apart from classifying genderization on the basis of technical parameters, there are also many social factors which affect the scenario in one way or the other. This is because certain practices or beliefs are ingrained in the minds to such an extent that people start considering it as an element of evaluation.

As per the survey designed by Harvard researchers to test the thought processes called the Gender-Career Implicit Bias Test [26], where it is concluded that men associate themselves with careers, while women associate themselves with family. The culture-oriented opinion that Mathematics is hard and women are sensitive to it is a well-documented stereotype threat [21]. However, in an ecosystem of chaotic work and unbridled hierarchy, both genders suffer from the loss of proper control over their tasks with respect to time. But ultimately the choice between career and family care rests on the woman's shoulders. For example, in a much talked about case, the first-ever female director of Policy Planning for the US government, Annie- Marie Slaughter, gave up her job due to the extreme work schedule which led to disregarding of her growing children [22].

A recent initiative from women working in the neurosciences field is a website called BiasWatchNeuro, its goal being "to track the speaker composition of conferences in neuroscience, particularly with respect to gender representation". The promoters hope that colleagues from other disciplines will soon join them with similar sites. [29]. A 2012 study by Jo Handelsman of Yale University and her colleagues shook the scientific community by reporting that science faculty members have a pervasive bias against female scientists [31]. This prevents many from doing their job of promoting the best scientists, and the society is paying a price in terms of the advancement of science.

Although there are shows such as the Star Trek and Television series such as "*Tomorrow's World*", which inculcate the spirit of Science in children, the media projects them from a masculine perspective. Unfortunately, young people are not immune to gender bias. Many studies have been conducted on college-age subjects, and gender bias has even been reported in preschool children [31]. Although researchers have found that "psychological androgyny" is essential for creativity, the history of human creative and intellectual endeavour is spotted with gender imbalances — nowhere more so than in science. This systemic problem is solved not simply by putting more women in the science and engineering sections of bookstores or on the TED stages or on the science faculties of higher education, but by encouraging younger girls to become scientists and engineers in the first place.

Kessels and Hannover [23] note that there are few female scientists to look-up to, which in turn made the female children to feel like the "*odd one out*". Wyer [24] observes that female children feel confident in their abilities to perform better in STEM subjects in single-sex classrooms rather than together with boys. Furthermore, Faulkner [25] records that gender bias in the classroom is one of the prime factors due to which women change their majors. Many women are deterred from pursuing a career in science and engineering at the highest levels. Much more must be done to address the reasons behind this potential waste of human talent. In practice, engineering requires social skills in working with varying nature of stakeholders, such as customers, coordinating workers, balancing teamwork and communicating with many different professionals involved in a large project. In reality women excel in these skills [26], however, such requirements are hardly advertised at the beginning of their programmes. As a consequence, very few women get into the traditionally male-bastion fields of Engineering. Some exceptions seem to there in the Indian sub-continent and the former soviet colonies (e.g., Poland has more female engineers than male engineers). Highlighting success stories will encourage qualified women to pursue careers in science. Role model and mentoring initiatives are also important to encourage women to pursue STEM and related disciplines.

7 Conclusions

In this paper, we have argued that various STEM disciplines and the various subjects/sub-fields in STEM themselves exhibit characteristics of feminine genderization. We conclude that the most disciplines of STEM have feminine characteristics and are consequently very suitable for females to pursue. Several aspects of STEM disciplines are well-suited to the female gender – just as the field like nursing (which is particularly suited to females) – even though the participation by females is low at present. We hope to improve the situation through early education of the feminine aspects of STEM disciplines to all students starting from the high school levels.

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Leveraging Professional Networks for an Equitable, Smart Society - A Case Study on the International Federation of Engineering Education Societies

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Abstract. Professional networks provide for the rapid exchange of important information, the facilitation of action around important tasks, and other activities that could lead to the promotion of equitable, smart societies. The field of engineering education has strongly relied on professional networks for growth as an academic field as well as for dissemination of scholarly findings and concrete impact. The International Federation on Engineering Education Societies (IFEES) serves as a global professional society for the field of engineering education and has worked to enhance global engineering education by leveraging its networks of engineering educators and partners. In its mission to lead global engineering education into the 21st century, IFEES has established strategic branches of actors and initiatives within its network to target global objectives: Top Down Academic Support, Capacity Building, Bottom-Up academic support [student involvement], and Cross-Sector Relations. IFEES acts a scholarly network and has developed a strategic plan in which linking actors to operate as a whole can provide return greater than the sum of its parts. These include best practices for academic leaders via the Global Engineering Deans Council (GEDC), capacity building with the International Institute for Developing Engineering Academics (IIDEA), student engagement with the Student Platform for Engineering Education Development (SPEED). These initiatives and partnerships are presented to illustrate how the IFEES network is leveraged to provide for success within the global engineering community.

1 Introduction

Since the 1990s, knowledge-intensive economies have developed nations and institutions in which research, its commercial exploitation, and other intellectual work are increasingly important [1, 2]. Global Research and Development (R&D) expenditures

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over the past decade have grown faster than global gross domestic products, indicating widespread efforts to make economies more knowledge- and technology-intensive [1]. These factors indicate increasing interdependence between industry, government, and educational institutions on a global level creating strong need for effective partnership and collaboration within global networks.

Since the industrial revolution, the competencies required of engineers and the outcomes of engineering education have been primarily determined by policymakers within individual countries. However, the contemporary global knowledge economy and increasing mobility of high-skilled labor has pressured an expansion of the conversation around engineering competencies beyond countries and into regional and global levels [3]. Today, engineers throughout the world must be prepared for international work as well as being employed alongside people who have been trained in other countries. As a result, engineering education institutions and professional societies are responding to this need [4]. In this work, we define smart society as a society in which individuals, organizations, and other institutions have access to the capability to engage in the global knowledge economy.

In order to create an equitable and smart society, access to this knowledge economy is critical, and engineers are seen as central to a robust knowledge economy [5]. The field of engineering education is therefore implicated to ensure that engineers obtain appropriate technical skills, social and ethical awareness, and the ability to synthesize these ideas within present and future engineering contexts. According to the 2004 NAE's report on The Engineer of 2020 [6], engineering graduates should collaborate across multiple fields to contribute to the global economy that produces rapid technological innovations and breakthroughs. In the last 15 years, engineering education research has emerged an established field with centers, departments, journals, conferences, and funding, to provide for intellectual growth. To date, approximately 30 graduate programs exist in engineering education alongside other institutionalized scholarly units [7]. With increasing efforts to build smart societies, it is imperative for current engineering students to go beyond these initial calls for increased student capacity and engage in creative and critical thinking, teamwork with diverse partners, ethical practice, and problem solving skills. This aligns appropriately to the increasing importance given to engineering education research, which is focused on building better engineering programs for current and future students.

Professional societies and professional networks are critical mechanisms for the sharing of resources and knowledge and have emerged as important mobilizers for the field of engineering education. Additionally, professional societies can support institutional and broader social responsibility dimensions of professional ethics and play an important role linking individual and professional ethics [8], even more important when emergent challenges have global implications. The International Federation of Engineering Education Societies (IFEES) is "a global membership organization of Engineering Education Organizations, Professional Societies, Student Organizations, Policymakers, Industry and Government Entities with an interest in advancing engineering education throughout the world." The IFEES vision is to "be the collective voice and change agent for achieving relevance, excellence, equity, access and diversity in engineering education worldwide" through its mission to "advance and advocate for engineering education and engineers worldwide by connecting, sharing resources and leveraging strengths of members and stakeholders" [9]. IFEES seeks to achieve this vision and mission through the global collaboration of its member societies and those within its network towards the establishment of effective and high-quality engineering education to support the development of well-prepared engineers who make significant contributions to changing the world. IFEES strives to strengthen member organizations and their capacity to support faculty members, students, and the professional workforce [9]. IFEES aims to enhance the ability of engineering faculty, students, and practitioners to understand the varied cultures of the world and to work effectively within them [10, 11]. Through close alignment with its member societies and several important strategic partnerships, IFEES promotes progress through several objectives: providing a forum for its members to leverage its resources, providing a community that will identify and advance the issues related to engineering education, defining the various profiles of the emerging engineer through stakeholders, and advocating and disseminating best practices to external stakeholders. As a federation of approximately 50 different engineering education professional societies and bodies, IFEES primarily acts as an inter-organizational connector, catalyst, or umbrella where it facilitates activities between its constituents.

This paper presents IFEES as a case study of a global professional networks which provides for an equitable, smart society through mobilizing action and collaboration within its engineering education network. Discussion on the emergence of the field of engineering education and engineering education research (EER) through collaboration and networks is presented followed by a brief background on collaboration and professional networks and how they are characterized provides a foundation. This is followed discussion on three strategic efforts of IFEES for collaborative impact on global engineering education. This is followed by discussion of the role that collaboration and networking through professional societies has played on the emergence and growth of the field of engineering education.

2 The Field of Engineering Education – Emergence Through Scholarly Collaboration

Multiple networks and collaborative structures have helped establish the field of engineering education. These include professional societies and groups of scholars as well as actions taken by governmental bodies, funding agencies. The emergence of engineering education as a field/discipline was initiated through the collaboration and partnership between scholars with engineering and interdisciplinary backgrounds and has evolved into a large research community with a growing number of academic publications, scholars, publication venues, and funding streams [12].

Conversations about engineering education as an area of scholarly interest began 100 years ago through the Society for the Promotion of Engineering Education (now American Society in Engineering Education - ASEE) [13]. As the U.S.A.-based professional society for the field of engineering education, ASEE was founded in 1983 and has since been playing a key role in shaping the field [14]. Around the same time, conversations in other parts of the world led to the creation of societies like the European Society for Engineering Education (SEFI, founded 1973), and other national and regional organizations [3]. ASEE has been instrumental in shaping the direction of engineering in USA to a large extent through many collaborative initiatives including the Mann report in 1918 [15], the Grinter report in 1955 [16] and the Goals committee report in 1968 [17].

The National Science Foundation, a governmental agency and funding body, played a major role in engineering education through initiation and funding of the Engineering Education Coalition (EEC). The EEC program's main goal was to produce new structures and fresh approaches within U.S. undergraduate engineering education, including both curriculum content and significant new instructional delivery systems [3]. In 2006, the Engineering Education Research Colloquies (EERC) brought together more than 70 engineering, science, and mathematics educators, researchers, and practitioners to address the challenges and future needs of engineering education. They identified five research areas for the discipline of engineering education: Engineering Epistemologies, Engineering Learning Mechanisms, Engineering Learning Systems, Engineering Diversity and Inclusiveness, and Engineering Assessment [12]. In 2007, the first International Conference on Research in Engineering Education (ICREE) was hosted to examine how engineering education is widely conceptualized as a discipline, community of practice, and field [18].

The impact that scholarly collaboration has had on the emergence of engineering education research (EER) has been investigated and reviewed by Xian et al. [12]. Additional studies have highlighted collaboration and networks within engineering education using bibliometrics to: analyze collaboration through papers and authorship to characterize the state of EER in terms of primary research areas, institutional infrastructures, research strategies, funding sources, publication outlets, and the country/setting in which the work was being performed [3]; summarize the current state of EER literature by providing an overview of scholar profiles, sources of support, types of publication, main topics, and major publication venues [19]; and study the collaboration pattern among engineering education scholars who have received funding from the NSF to identify how the collaboration varied by research area [12]. Based on a topographical analysis performed through bibliometrics, Xian et al., have found that as of the time of publication (2008) the engineering education research community was in the early stage of forming a small-world network in that it relied primarily on 5% of its scholars to build capacity. Various factors have been identified to affect collaboration in Engineering Education: scholars' fields of study, geographic locations, research areas, culture, and language [3, 12, 20–23], however, little is known about how these factors contribute to scholarly collaboration in engineering education research or practice [12].

Ultimately, the scholarly efforts cited above suggest various findings which can characterize the collaboration status in engineering education, inform policy making for improving collaboration, and help individual scholars to recognize potential collaboration opportunities [3, 12]. In comparing with other disciplines and the ideal small-world network model, the topology of collaboration in engineering education shows significant barriers to the fast diffusion of innovations [12]. Promoters of increased collaboration and outcomes within networks include: opportunities for open communication; in-person meetings; scholars with interdisciplinary backgrounds; key players bridging isolated research [3, 12, 20–23]. On the other hand, barriers that inhibit outcomes within collaborative networks: engineering education scholars rarely communicate or collaborate with engineering researchers from different disciplines [24]; disciplinary barriers lead to silos and limited cross-fertilization in EER [24]; publications have limited effect on influencing engineering departments' adoption of EER innovations [25]; a division exists between core engineering education scholars and the wider engineering community [26]; the network in engineering education exhibits an attachment bias where new node linkages favor the highly connected nodes [27]; differences in culture and language are barriers in scholarly communication and collaboration [22]; cross-national differences in access to/amount of publications in English/western based journals.

3 Collaboration Networks and Professional Societies

Leveraging professional networks towards the development of an equitable and smart society requires collaboration, which can take many forms. This section provides a brief overview of collaboration and social networks, including some of the factors and theories used to characterize and describe collaboration within networks.

Scholarly collaboration plays a critical role in sustaining advancement of any academic discipline [12]. When the knowledge base of an industry or field is both complex and expanding and the sources of expertise are widely dispersed, the locus of innovation will be found in networks of learning, rather than in single institutions [28]. Various structures can facilitate collaboration including networks (social, affiliation, collaborative, or epistemic) [12]. Professional societies can often be categorized as one or several of these types of networks. Collaboration can lead to new solutions to complex problems [29]. It has been defined as cooperative, interorganizational relationships that are negotiated in an ongoing communicative process and that rely on neither market nor hierarchical mechanisms of control [30, 31]. The solutions developed through collaboration can be adopted far beyond the boundaries of the collaborative process, acting as a source of innovation which can help to promote innovation within a field or discipline [30, 32]. These innovations can emerge within institutional fields through the generation of "proto-institutions," where new practices, rules, and technologies can transcend a particular collaborative relationship and may become new norms within a field if they diffuse sufficiently [33].

There has been longstanding recognition of the need to promote collaborative problem solving across various sectors of society, e.g., among business, government, labor, and communities [34]. This is said to be especially true during crises, or when confronting indivisible problems (problems which are bigger than any single organization acting alone can solve [35]) and/or amid turbulence (when large, competing organizations, acting independently in diverse directions, create unanticipated and dissonant consequences for themselves and others) [34, 36]. These types of challenges impose limitations on single, bureaucratic organizations ability to solve them independently [34]. The impending challenges of engagement with growing and changing knowledge economies, as well as the issues described by the NAE Grand Challenges could be characterized as indivisible and turbulent.

Networks take many forms. A social network is a social structure made up of a set of actors and the ties or connections between some or all of the components [12, 37].

The actors (nodes) are often made up of individuals, groups, or organizations. An affiliation network is a network of people connected by common membership in groups of some sort. A semantic network is a set of concepts and their semantic relations [12, 38]. Networks of a researchers are often referred to as scholarly collaboration or scientific collaboration networks, in this work, we are including professional societies within this classification as they exhibit both social and semantic network characteristics [12]. The integration of social and semantic concepts within a network cause the emergence of an additional type of network. These epistemic or socio-semantic network are defined as "a group of agents sharing a common set of subjects, concepts, issues, and a common goal of knowledge creation" [39]. While the goal of professional societies is not limited to knowledge creation it is often included amongst other objectives to provide for professional development, growth, and impact within a specific context.

Understanding structures for collaboration within these networks is a data-intensive process [12]. Network structures can be represented in network maps where nodes/vertices are used to represent actors/agents which are connected by edges/links. Research within networks have established outcomes concerning social influence, social groupings, inequality, disease propagation, communication of information, and sociology [37], and have indicated the importance of network structures and their implications on the spread of information. Empirical and theoretical analyses of social networks [40–43] have characterized network topologies based on grouping scholars by disciplinary backgrounds, research areas, and geographical locations were performed. One approach to analyze these networks is through analyses of publications, called bibliometrics, which is a method designed to qualitatively evaluate publications, scholars, journals, and institutions based on large-scale publication metadata [44].

An understanding of several factors commonly used to characterize the many types of networks as well as the network cohesion [12, 40] is provided as a foundation to the discussion in later sections to broadly describe the IFEES network:

- Cluster: A group of interconnected actors within a network - larger clusters within a network indicate a large number of scholars have the potential to reach each other via the connections in between them;
- Path length: the amount of connections between any two actors within a network or cluster - a long average path length indicates that nodes are less likely to connect within a cluster and the dissemination of outcomes is inhibited;
- Degree of network: number of acquaintances which individuals have - a higher average degree indicates that scholars have more collaborators;
- Attachment bias/degree distributions: The extent to which nodes within a network demonstrate preferences when making connections rather than equal probability/randomness of connection forming - this process is often called "preferential attachment" [41] or the "rich get richer phenomena" [45].

Two theories have been used to analyze scholarly collaboration networks: the diffusion of innovations theory [42, 46] and the small-world network theory [33]. Diffusion of innovations theory recognizes factors that affect the adoption of knowledge, highlighting the importance of scholarly communication and collaboration in advancing innovation [12]. We use this theory to situate our case study in our final discussion section. The small-world network theory characterizes a network model that mimics real-world social networks to describe a network topology that exhibits characteristics of both regular networks and random networks [47]. In these small-world networks, most nodes are involved in a highly clustered local network but also interact with nodes in other networks through a small number of links. Small-world networks can provide characterizations about the state, stability, and growth of the community [12]. Deviations from this type of network model imply longer distances between individuals which inhibit the spread of innovations. Scientific communities often seem to constitute a “small world” where only about five or six steps are necessary to get from one randomly chosen scientist in a community to another which is a crucial feature of a functional scientific community [37].

While this work does not seek to characterize the IFEES network, it will leverage outcomes and structures of network analysis, scholarly collaboration, and efforts within engineering education to frame our discussion.

4 Case Study: The International Federation of Engineering Education Societies

As shown, professional societies and other organizations leveraging collaboration have played a significant role in the development and progress of the field of engineering education since its inception. Organizations advocating for engineering education have extended beyond countries to both regions and the world, motivated by the increased mobility of engineers and a model of competition among countries in terms of economic competitiveness [3]. There have been calls for more collaboration within the engineering education community [24, 48]. It is from such opportunities, which parallel IFEES’s efforts to structure itself as a catalyst for increased collaborative outcomes, that IFEES emerged. We qualitatively examine the way in which some of these factors have contributed to professional collaboration in engineering education from a global perspective.

As described above, IFEES was established when several Engineering Education Societies were already mature (SEFI, ASEE) and had already developed substantial dialogue about local problems. IFEES was founded when it was realized that, beyond similar local problems discussion on problems of international character were necessary. To accomplish this, concerted action by these established societies, as well as a global community to build collaborative links to more stakeholders from various regions was critical. The engineering education community recognized the global economy spurred the creation of turbulent challenges of complex nature that required international collaboration to solve. Established in Rio de Janeiro in 2006, the International Federation of Engineering Education Societies (IFEES) has worked towards global coordination of engineering education activities for 10 years. As a federation comprised of many engineering education societies, collaboration and alignment of stakeholder action is leveraged towards the progress of the actors, the institutions, and the field of engineering education.

These objectives are approached through delivering opportunities to collaborate and interact with peers and other stakeholders within the following realms: diversity and inclusion, industry university partnerships, e-learning, student retention, R&D collaboration, curriculum collaboration, international experiences, networking, funding sources, and educational best practice. The activities are executed across 4 different kinds of stakeholder groups/in 4 different directions through the network. The actors within these initiatives seek collaborations across and within these different stakeholder groups. IFEES has demonstrated collaboration between multiple sectors of society as an approach to solve complex and turbulent problems being faced by society.

5 The Strategic Collaborations Within the IFEES Professional Network

IFEES has established several strategic partnerships with seek to systematically establish and leverage different clustered groups of stakeholders within engineering education. The ties between academic leadership is clustered through the Global Engineering Deans Council which establishes a top down approach. Engineering student leaders are mobilized to be actors in the global engineering education network through the Student Platform for Engineering Education Development for bottom up activities. Capacity building, through the International Institute for Developing Engineering Academics, helps spread the innovations of the field of engineering education to differing actors within the global network for the development of increased key players throughout the world to strengthen the network. These examples are presented illustrating examples of how the IFEES network functions as a collaborative network.

a. *Top Down Academic Support - The Global Engineering Deans Council (GEDC)*
An early and distinguishable outcome of IFEES resulted from representatives working together to develop the vision of an international platform for engineering Deans, which resulted in the creation of the Global Engineering Dean's Council (GEDC) [49]. Engineering deans from all continents gathered in Turkey during the annual Summit of IFEES to formally create the Global Engineering Deans Council (GEDC). The GEDC membership has grown from a social network of 20 to over 100 members from almost forty geographically dispersed countries. Deans from similar geographical locations formed additional socio-semantic networks resulting in the formation of four regional chapters. Currently GEDC comprises a global network of deans with a degree of approximately 300 and also includes ten corporate members, who have continually supported the work and mission of the Council [49].
Engineering education scholars rarely communicate or collaborate with engineering researchers from different disciplines [24], and scholarly research publications exert a limited influence engineering departments' adoption of EER innovations. GEDC, which currently serves as the only global network of engineering dean's leverages the collective strengths of participating deans for the advancement of engineering education practice and service to the global community of engineering schools and partners. Through annual conferences and other meetings, GEDC provides a venue for engineering deans to discuss emerging issues in the field and develop appropriate solutions that materialize from work of engineering education researcher and

practice. Each of the deans follows the small-world network theory by forming an additional local network to continue facilitating similar discussions at their institutional level and implement best practices at the departmental level. Several important outcomes of the GEDC have had strong impact within the global engineering community including the establishment of a global online presence for Deans, regular meetings between Deans, and the creation and support of the GEDC Airbus Diversity award, which seeks to take direct actions at increasing equality within engineering education.

b. *Bottom Up Academic Support - The Student Platform for Engineering Education Development (SPEED)*

The Student Platform for Engineering Education Development (SPEED) is a global non-profit student organization which empowers students to engage with engineering education (EE) discussions, research, faculty and instructors, and other leadership opportunities [31]. SPEED was founded by a group of engineering students in 2006 during the ASEE Global Colloquium in Rio De Janeiro, Brazil and was established by students to provide perspectives from one of the primary stakeholders which IFEES and engineering education serve – students. The emergence of SPEED coincides with other actions across the network as student leaders encouraged bottom up development recognizing that collective action would be more effective to accomplish organizational objectives and not possible without student participation. SPEED has continually worked to build a social network through establishing links with IFEES leadership and member societies towards growing the student voice, impact, and leadership within the global community.

SPEED conducts an annual Global Student Forum (GSF), often alongside the World Engineering Education Forum (WEEF) [50]. The GSF gathers students from across the globe and engages them in discussions about engineering education and its relation to other pressing societal challenges. During the 3-day Forum, students brainstorm solutions to various proposed challenges they face and ideas to overcome them. Participants are later provided with tools to develop an action plan. These action plans are later implemented in their local regions after the completion of the Forum [51]. All action plans are developed from a global perspective and implemented locally. Cultural competence, professional networking skills and opportunities, community service, and other components are consistently part of the Forum.

Since its inception in 2006, SPEED has conducted 11 GSFs in locations around the world: Rio De Janeiro, Istanbul, Cape Town, Bhubaneswar, Budapest, St. Petersburg, Singapore, Buenos Aires, Cartagena, Dubai, and Florence. The most recent edition of the GSF was held in Seoul, with the theme of "Empowering the Millennials", and it focused on four of the eight Millennium Development Goals articulated by the United Nations [52]. The action plans developed were focused towards achieving universal primary education, eradicating extreme poverty and hunger, promoting gender equality, and ensuring environmental sustainability. National Student Fora also emerged as part of the SPEED agenda beginning around 2010, being organized in Mexico, Australia, Argentina, Colombia, and India [53–55] by members of SPEED who had previously participated in the GSF. In line with the small world network theory, these national fora contributed to the formation of multiple local networks regionally. These local networks envisioned impacting students in their respective regions, acting as satellite activities furthering SPEED's mission. Future plans have been formulated to organize one national student forum on every continent each year going forward.

To support the ongoing efforts in building engineering education scholarship, SPEED is encouraging students to perform research within Engineering Education and consider the field as a career option. This focus aligns with the larger goal of having a more diverse engineering education community who will work towards its development in future. SPEED launched the 'Research Scholarship Program' which is awarded to two students every year based on student research efforts. The winner of the award receives funding to attend the conference to present the submitted paper [56]. SPEED has also collaborated with International Society for Engineering Education and Modern Engineering Pedagogy (IGIP) and the Ibero-American Science and Technology Education Consortium (ISTEC) to launch two separate awards, which seek to recognize key student leaders and their efforts within engineering education. SPEED's most recent initiative has been the launch of the SPEED research group. Due to the fact that a majority of the current EER scholars have an engineering background [12], engineering students collaborate with SPEED members from the social sciences background to build EER skills. Through this interdisciplinary collaborative initiative, SPEED plans to build a socio-semantic network of students interested in EER. In the coming years, SPEED intends to mobilize more students across all the continents through national and regional student forums to engage a larger ratio of students into the global community of engineering education.

c. *Capacity Building - The International Institute for Developing Engineering Academics (IIDEA)*

Established in 2010, IIDEA is an engineering education leadership training institute focused on establishing a global network of engineering faculty development programs to disseminate learning about the transformation of engineering education worldwide [57]. IIDEA works to increase the size of the global engineering education network by reducing the division that currently exists between core engineering education scholars and the wider engineering community [26]. It aims to bring together a global network of engineering education scholars who can provide engineering education associations, institutions, and other stakeholders a clearinghouse of high-caliber and world-class engineering faculty leadership training workshops, certification programs and seminars. These workshops are available to IFEES member organizations and other interested parties as stand-alone or as pre-/post conference activities. IIDEA is a joint initiative of IFEES and SEFI (European Society for Engineering Education), whose leadership recognized the need to create a central place where engineering education institutions could come to search for capacity building opportunities.

IIDEA has offered many workshops around the world, reaching out to hundreds of faculty, deans, and other engineering education leaders. Content and length of workshops are customized to the needs of the participants. They can range from

3 h to 3 days and involve one to three facilitators. Presented in a walk-the-talk manner, workshop facilitators practice what they preach and utilize active learning to engage with attendees. Industry partners are invited to support, participate, and contribute to IIDEA activities. This has promoted strategic partnerships to address regional needs. One example is the 6-year long multi-stakeholder, multi-national partnership to enhance engineering education in China [58]. With the support and contribution of industry partners, the Chinese Society for Engineering Education (CSEE), the Chinese Academy of Engineering and Tsinghua University (THU) and its Center for Engineering Education (CEE) and Institute of Education (IOE) have partnered with IIDEA to provide leadership and capacity building to more than 600 engineering professors, deans, and leaders through workshops and discussions. Various engineering education areas have been addressed in workshops, including learning environments to bridge the gap between how we teach and the practice of engineering, problem-based learning, innovating the engineering curricula, building and nurturing industry-university collaboration, faculty development and accreditation, ethics across the curriculum, teaching/learning excellence centers. This unique multi-stakeholder, multi-national partnership focused on catalyzing innovation in engineering education. It is a model that other regions and countries are adopting.

6 Discussion

Moving forward, it will be imperative for IFEES and other engineering education stakeholders to continue providing for the exchange of best practices, the development of mutually beneficial collaborations, and to act as a global community for Engineering Education researchers, practitioners, and allies. Collaboration efforts can focus on efforts that enable the dissemination of skills, research, and resources from experts within and between different regions of the world. Continued focus on capacity building in different nations, especially in developing countries to promote the integration of engineering education innovations into research and practice, will broaden. Partners and relevant regional organizations can be supported to develop capacity building that will enhance the capabilities of engineers and engineering educators to develop endogenous technology that is capable of promoting the growth of the economy.

These collaborative efforts can lead to increased partnership with scholars from differing and interdisciplinary backgrounds. Actors with these backgrounds have been shown to serve as bridges between otherwise disconnected groups as well as play a far more significant role in bridging with other disciplines, have a large number of links, as well as play more significant roles in diffusing engineering education innovations and forming new links [12]. Key players, similar to those who are interdisciplinary, can bridge networks and are often located in the center of clusters. IFEES and its strategically formed clusters are networks made up of these key players and interdisciplinary players.

The results established by Xian indicate that within engineering education research the small-world network characteristics are forthcoming within EER. IFEES and other professional societies can promote the development of small-world network characteristics within its efforts through increasing degree of collaboration. Minimizing the path lengths between the actors to promote the diffusion of innovations. IFEES, other engineering education bodies, and engineering professional societies must continue to push for more. Additionally, traditional efforts of organizations such as conferences and in person meetings continue to have be significant due to the importance of geographical proximity affecting collaboration network topology [12]. Continuing to provide structures that bringing people together can significantly improve how research innovations are diffused but when not possible the continued emergence of collaborative and communication technologies, such as the IKNEER network [59], can help eliminate the barrier caused by physical distance [12].

In professional societies and collaborative networks, a strategic plan serves as an agreement between the stakeholders (members of the organization) and those who were appointed to lead the organization [60]. For any organization, strategic planning is a valuable tool for ensuring success. It is a process of devising a series of attainable steps that will both propel the nonprofit toward a more accomplished future and help it to focus on successfully fulfilling its mission. The two basic assumptions behind strategic planning are that the final documented plan will be of import and substance germane to the organization and that it is a snapshot of the organization at the present time, with the objective of moving the organization toward its future [61]. According to Bryson, environments of public and nonprofit organizations have become not only increasingly uncertain in recent years but also more tightly interconnected; thus, changes anywhere in the system reverberate unpredictably-and often chaotically and dangerously-throughout the society. This increased uncertainty and interconnectedness requires a fivefold response from public and nonprofit organizations (collaborations and communities). These organizations must think and learn strategically as never before, recognizing the outcomes from social network analyses and leveraging them to inform strategic plans and appropriate actions. They must translate their insights into effective strategies to cope with the impacts of globalization on the role of engineers and engineering education. They must build coalitions that are large enough and strong enough to adopt desirable strategies and protect them during implementation. They must build capacity for ongoing implementation, learning, and strategic change [60].

In its newly developed 2016 Strategic Plan, IFEES states that it will promote the following core values among its members and in all of its activities: Excellence and quality in engineering education; A culture of community building and collaboration among all stakeholders and across all diversity borders; An engineering educational experience and profession which displays integrity, honesty, mutual respect and sensitivity to cultural, economic, and geographic issues of its stakeholders.

Strategic thrust areas have been defined to include an increase in IFEES membership, increased partnership opportunities with like-minded organizations, continued support within the network of students, faculty, and partners (institutions and industry), continued promotion quality assurance (QA) of engineering education, an increased participation in the World Engineering Education Forum (WEEF), attention to diversity and inclusion across the world, and the continued development capacity building in engineering education. It is IFEES' belief and strong desire that this strategic plan guide appropriately guide the organization towards continued success and the continued development of impactful outcomes. IFEES also recognizes individuals who have made significant contributions to the global engineering education community. The IFEES President's Award for Global Visionary has been awarded to individuals who have had a long career in engineering education, with a strong reputation and credibility as global leaders. The IFEES Duncan Fraser Global Award for Excellence in Engineering Education recognizes individuals who have made innovative and meritorious contributions having a significant impact on the advancement of engineering education.

Research in core engineering disciplines has recorded success overtime and international collaboration in different areas is evident, however global levels of engineering education research require attention. Key areas of research have not been adequately supported, especially in developing countries. IFEES will continue to endeavor to identify institutions that serve as centers of excellence in engineering education research and promote collaboration between researchers in different regions of the world through such centers.

7 Conclusion

Through the facilitation of IFEES, member societies have continued establish themselves as key players for improving quality of engineering education in hundreds of engineering institutions around the world. An ecosystem has been built to network, educate, benchmark, and share best practices through partnerships and initiatives for the continuous quest of excellence in engineering education. The multiple stakeholders collectively qualify the Federation as "a catalyst" to reflect that it is indeed an enabler of action and does not sign its own achievement but rather initiates their conceptualization. This role is challenging, thus, to keep inspiring changes and innovation in engineering education that are relevant to engineers in development, employers, and ultimately to society, IFEES will have the challenge in the coming years to assert its contributions in a more visible manner.

Ultimately, recognizing the characteristics and structures which can enhance collaboration within networks can be useful in informing the actions taken by professional societies. In summary, efforts to increase the size of any cluster within a professional society can increase the diffusion of innovations and outcomes throughout the network. However, with attention placed on not only increasing the size, but also ensuring that attention is granted towards maintaining a high degree and maintaining small path lengths within any cluster will ensure that a broader number of the actors are involved, active, and providing outcomes. Capacity building can broaden the actors with critical knowledge to perform within the network as well increase the ability of actors from other disciplines to move from the periphery of organizational networks into the center. The promotion of the development of key players within the network will limit attachment bias and establish a more equitable probability in connections forming between all actors. These efforts taken collectively across a professional society or social network will contribute to the establishment of a stronger network.

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Innovation in Engineering Education

Section: Innovations in Engineering Education

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All engineering education conferences, summits, fora worldwide address - in some way or manner -innovations made by engineering education's stakeholders. It is these ideas and projects that help educators become aware that change is possible and mark the path of innovating their classrooms, their programs, their ecosystems. Such is the case of WEEF 2016 in Seoul, South Korea, which main title was Engineering Education for a Smart Society. This section includes some of the best papers shared by colleagues from various parts of the globe in Seoul. Innovations that stem from the need to shift from teacher- to student-centered education, engaging in active/authentic learning such as entrepreneurship and environmental learning to understanding faculty perceptions of communication skills development. I hope the reader enjoys perusing these experiences and becomes motivated to continue to search for others in the quest for enhancing the excellence of engineering education to better serve the smart society we live in.

Recommending Exercises in Scratch: An Integrated Approach for Enhancing the Learning of Computer Programming

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Abstract. In this chapter we focused on how to improve the learning of computer programming in college students. From the reported success, we relied on Scratch, a visual programming language for enhancing the informal learning. Despite the progress achieved in the past, we have observed some issues regarding the use of Scratch by college students. First, there is a gap between the employed learning approaches since professors are constrained to classroom activities. Second, certain students feel unmotivated because they are confronted with programming exercises that do not fulfill their individual expectations. So, in order to solve this issue we propose an integrated approach consisting of a simple Web Application that includes Scratch as a project editor along with an Recommender System for exercises. The preliminary results demonstrate the positive impact of our proposal.

1 Introduction

In traditional education approaches (e.g., schools), professors play an important role because they guide the learning process according to a considered structure of the subject. In other words, the knowledge is revealed to the student in an organized way. This is frequently called formal learning (European Centre for the Development of Vocational Training 2014). Regardless of the benefits of such an educational model, over the last 20 years the so- called Technology Enhanced Learning (TEL) has raised alternative models. TEL has been defined as an application domain that covers technologies for supporting all forms of teaching and learning activities (Manouselis et al. 2011).

One important example of TEL in the context of programming education is Scratch (Malan and Leitner 2007), a visual programming language developed

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and maintained by the Massachusetts Institute of Technology (MIT). Thanks to its intuitive style, Scratch significantly reduces the learning curve in children and beginners in computer programming. The key educational approach promoted by Scratch is informal learning (European Centre for the Development of Vocational Training 2014). Basically, this is because students are free to create, explore and reuse programming projects without the teacher's presence. In this way, Scratch can also be used for supporting the formal, or traditional, teaching of computer programming in educational environments.

There are some examples of the use of Scratch in higher education (e.g., college) in introductory Computer Science courses with Scratch, this language successfully familiarized inexperienced students with the fundamentals of programming (Malan and Leitner 2007). Similarly, Scratch has been shown to help students understand programming by offering a different perspective from traditional environments (Wolz et al. 2008). The same authors reported that the transition of the students to Java or C programming languages becomes easier after learning Scratch (Wolz et al. 2009).

Since there are benefits to merging formal and informal learning, we have included Scratch as an educational resource for teaching the subject of Foundations of Computer Programming at Universidad Estatal de Milagro (UNEMI) (Ecuador). Since this started in 2015, there has been an increased motivation and academic performance among the students. Nevertheless, some issues pertaining to the usability of Scratch were also noticed: (i) there is a gap between the employed learning approaches since professors are constrained to classroom activities, and (ii) certain students feel unmotivated because they are confronted with programming exercises that do not fulfill their individual expectations (e.g., exercises are too easy/too complex). This latter issue has been experienced previously (Tanrikulu and Schaefer 2011).

Thus, the question arises: How to improve learning with Scratch, while saving the gap between formal and informal learning approaches, and allow students to do exercises according to their levels of knowledge and previous experiences? An intuitive and effective solution to this problem comes from Recommender Systems (RSs) (Herlocker et al. 2004; Ricci et al. 2011). Literature reflects several examples of significant benefits of RSs in educational environments (e.g., reviewed in (Manouselis et al. 2013; Klašnja-Milićević et al. 2015)).

Bearing in mind the above motivations, in this chapter we propose an integrated approach to improving the learning process with Scratch for college students. This approach consists of a simple Web Application that includes Scratch as a project editor along with an RS for exercises (i.e., problem statements). These exercises are created by the professor and included in the system. Thus, the student can access the exercises, solve them with Scratch, and evaluate them according to two criteria: appeal and complexity.

Based on the record of evaluated exercises, the system recommends new exercises to the student via a collaborative filtering approach. The assumption is that students with similar evaluations over a given set of exercises are a good source for recommendation. From a pedagogical perspective, this proposal can be considered a mediator between formal and informal learning approaches. In other words, it not only fills the gap between professors' lectures and student interaction with Scratch, it also helps to develop autonomous learning.

The rest of the chapter goes as follows: Section 2 provides a brief overview of Scratch. Next, we review related works about Recommender systems in learning environments (Sect. 3). In Sect. 4 the proposed approach is presented, being some preliminary discussed in Sect. 5. Finally, the conclusion and future works are outlined in Sect. 6.

2 What Is *Scratch*?

Scratch is a free visual programming language (VLP) created by the MIT Media Lab Lifelong Kindergarten Group in 2005. A VLP maps components of high-level programming languages into equivalent visual concepts (Jost et al. 2014). So, VLPs can significantly reduce the learning effort in beginners of computer programming (e.g. children). This is the case of Scratch.

Currently, Scratch goes beyond a simple VLP, it also involves an online community and other websites devoted to share projects and experiences. In Fig. 1 the home page of the Scratch website is shown. One important example of these websites extending Scratch is *ScratchED*[1]. It is developed and supported by the Harvard Graduate School of Education.

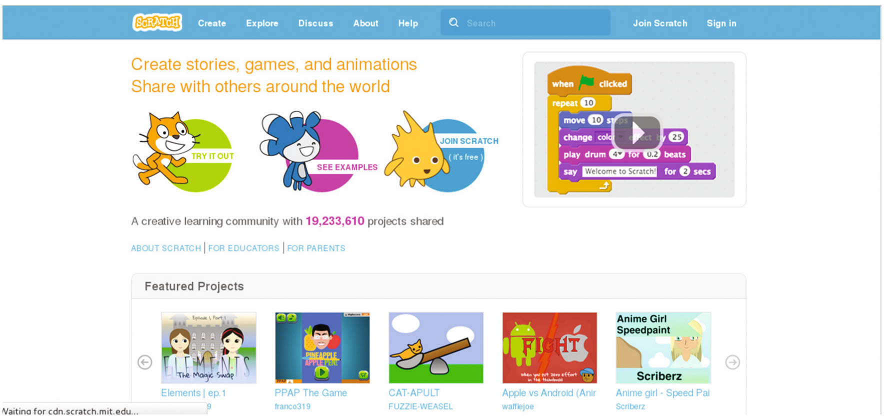

Fig. 1. Scratch environment.

ScratchEd involves an online community where Scratch educators share stories, exchange resources, ask questions, and find people. This project organizes the educational resources by means of categories, such as: Education level, Context type, Curricular area and Language. For example, the Education level category incorporates resources for all educational levels, that is, from the Preschool

[1] http://scratched.gse.harvard.edu/

and Kindergarten to College and University. Particularly, in the last level more of 326 resources exist for enhancing the autonomous learning in college students.

In order to illustrate how certain computer science concepts can be mapped into Scratch's visual components consider Fig. 2. It corresponds to a fragment of a resource named *Computational Concepts Supported in Scratch* appearing in the ScratchEd website. Notice that since the resource is in tabular form it is very self-explanatory. For sake of simplicity consider the third row corresponding to the *random* concept. As stated in column *Explanation*, using the *pick random* component a random integer number can be generated within a given range. The corresponding example depicted in the column *Example* gives a clear idea of how to use such a component in the Scratch language.

Concept	Explanation	Example
sequence	To create a program in Scratch, you need to think systematically about the order of steps.	go to x: -100 y: -100 glide 2 secs to x: 0 y: 0 say Let the show begin! for 2 secs play sound snap until done
iteration (looping)	*forever* and *repeat* can be used for iteration (repeating a series of instructions)	repeat 36 play drum 12 for 0.25 beats move 10 steps turn 10 degrees
random	*pick random* selects random integers within a given range.	set x to pick random -100 to 100
conditional statements	*if* and *if else* check for a condition.	if x position > 200 then set x to -200 wait .01 secs
boolean logic	*and*, *or*, *not* are examples of boolean logic	if touching color ? and x position > 200 then play sound meow until done

Fig. 2. Mapping of Computer Science concepts into Scratch's components.

3 Recommender Systems and Learning Environments

An RS is a software tool that seeks to determine, and suggests, what a particular user will find useful (Ricci et al. 2011). It is also considered to be part of the so-called information filtering system, which exploit the user information for predicting ratings or preferences that the user would give to an actual item (Bobadilla et al. 2013; Lu et al. 2015). Thus, the basic benefit of an RS is that it finds the most suitable set of items for a target user by maximizing its rating prediction.

According to (Ricci et al. 2011) five types of RSs exists: content-based, knowledge-based, demographic, community-based, collaborative and hybrid. Collaborative Filtering RSs have been perhaps, the type most widely used (Desrosiers and Karypis 2011; Elahi et al. 2016). It is built on the assumption that one user may like items that other users with similar tastes liked in the past. This is more or less the assumption adopted for the RS that was implemented in the present work. Specially, CFRS involves two major approaches: user-user and item-item (Elahi et al. 2016). In general, both approaches rely on the Nearest Neighbors algorithm (Desrosiers and Karypis 2011).

One of the major areas where RSs have been broadly applied in e-learning environments. That is, within the context of TEL (Manouselis et al. 2011) to improve the student's autonomous learning. While in e-commerce domains RSs suggest products or services to clients, in e-learning environments, RSs suggest educational resources (e.g., papers, books, courses) to educational participants (e.g., students and/or teachers).

Related literature shows a wide variety of works proposing RSs for e-learning environments. Some of the most important works in the field are briefly explained next. For an in-depth survey, the reader is referred to (Manouselis et al. 2013) and more recently to (Klašnja-Milićević et al. 2015).

The RS *CourseAgent* was conceived with the idea of enabling students to provide feedback in implicit and explicit ways (Farzan and Brusilovsky 2006). This RS allows the students to directly evaluate courses with respect to (i) their relevance regarding each career goal and (ii) the level of difficulty of the course. Both parameters provide implicit feedback when students plan or register in a course. The basic and evident benefits of this RS for the students are that (i) it constitutes a course management system that retains the information about the classes taken, and (ii) it facilitates communication with student advisors.

The Virtual University of Tunis develops automatic recommendations in e-learning platforms (Khribi et al. 2009). They are composed of two modules: an offline module that pre-processes data to build learner and content models; and an online module that uses those models *on the fly* to recognize student needs and goals, and then predict a recommendation list.

It has been argued that traditional RSs are not suitable for supporting e-learning because, up to now, they have not taken into account two important mechanisms: the learning processes and the analysis of social interaction (Wan and Okamoto 2011). To deal with these issues, the authors of the argument proposed a flexible approach involving a multidimensional recommendation model and a Markov Chain Model. The results showed that more suitable recommendations can be obtained from that approach. Similar research with a personalized approach was proposed. It relied on data mining and natural language process technologies for determining learner relationships based on learning processes and learning activities (Wan et al. 2011).

In order to guide learners in personalized, inclusive e-learning scenarios, an important analysis was conducted on how RSs can be applied to e-learning systems (Santos and Boticario 2011). In that study, three technological requirements for developing semantic education RSs were provided. Other authors have reported successful experience using similar ideas. See for example (Ghauth and Abdullah 2011; Lee et al. 2012; Dwivedi and Bharadwaj 2013; Tewari et al. 2015).

A framework for rapid prototyping of knowledge-based RSs was also reported in (Ruiz-Iniesta et al. 2012), and was used for recommending learning objects. From a software development perspective, the proposed framework is flexible enough for implementing new approaches since it includes default implementations of alternative strategies for each of its five stages. Two RSs were implemented in order to illustrate the benefits of this framework.

Related to the technological benefits of RS in education, there are subjective dimensions in this topic which are also important to study. For instance, a psychological view to learning with personalized RSs was provided by (Buder and Schwind 2012). Here, a very good fit between the main features of RSs (collective responsibility, collective intelligence, user control, guidance, personalization) and the principles in learning sciences is demonstrated. However, the authors claim that a "recommender systems should not be transferred from commercial to educational contexts on a one-to-one basis, but rather need adaptations in order to facilitate learning." In this context, some potential adaptations were grouped into system-centered adaptations (e.g., for enabling proper functioning in educational contexts) and social adaptations (e.g., for addressing typical information processing biases).

Similar to the previous work, in (Peiris and Gallupe 2012) a conceptual framework is proposed for explaining how evolving recommender-driven online learning systems (ROLS) support students, course authors, course instructors, system administrators and policy makers in development. Moreover, this framework involves two important perspectives in the constructivist paradigm of learning: *cognitive* and *situative*.

Additionally, an interesting approach to enhance RSs in collaborative learning environments has been presented in which an influence diagram included the observable variables for assessing the collaboration among users (Anaya et al. 2013). By applying machine learning techniques, the influence diagram was refined to increase its accuracy. The main outcome of this work was the development of an automatic RS together with a pedagogical support system in the form of a decision tree, which provides visual explanation to the user.

A generic cloud-based architecture for a system that recommends learning elements according to the affective state of the learner was also presented (Leony et al. 2013). The authors also provided some use cases, explaining the implementation of one of them. Undoubtedly, this is an interesting technological solution for exploiting cloud-based learning environments, which is a common feature in many education institutions.

An important survey on how to evaluate RSs was conducted in the context of TEL (Erdt et al. 2015). From an in-depth survey obtained from 235 works on the subject, it was concluded that there is an important interest in designing better strategies to evaluate RSs in TEL. Future trends and research opportunities were also highlighted in the study.

Summarizing the above review, three important conclusions can be drawn:

1. using RS in educational environments is a popular research topic with an increasing number of studies;

2. most of the existing works are technology-based, that is, they proposed RSs for enhancing the learning process. In contrast, just a few works employ a subjective perspective like (Buder and Schwind 2012) for analyzing the role of RS in this context; and
3. up to our knowledge there are not RS supporting programming learning with Scratch.

Conclusions 1 and 3 gave us additional reasons for proposing the system explained next.

4 Scratch+ERS: An Integrated Approach

The system proposed in this chapter aims to improve the current state of teaching Foundations of Computer Programming at Universidad Estatal de Milagro (State University of Milagro), Ecuador, with Scratch. Figure 3 helps demonstrate both the current and the proposed approaches for such a process.

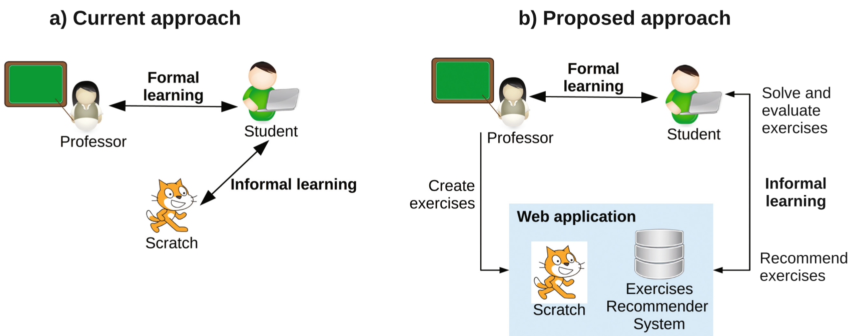

Fig. 3. Comparison between the current and the proposed approaches.

In the first approach (Fig. 3a), the professor interacts with students exclusively by means of classroom lectures (formal learning). The students use Scratch in the traditional form, that is, by creating or modifying projects (informal learning). Despite the benefits of this method, the professor has difficulty controlling the efficiency of the students' interaction with Scratch (i.e., whether the students are properly traversing the knowledge levels in which the course is organized). In light of these facts, a gap between the informal and formal learning approaches is observed. In addition to this issue, as we observed over the course of one year, certain students were not satisfied with the complexity of the exercises they are asked to solve with Scratch. For instance, the more experienced students are faced with too-easy Scratch projects.

A possible solution for these issues is a personalized set of exercises for students. (An exercise is defined in the context of this research as a problem statement that the student can solve in Scratch.) However, this demands an individual characterization of the students in order to assign to them the most suitable set of exercises, according to their knowledge level and expectations. This is a difficult task for the professor, mainly because there are too many students and exercises to assign. Moreover, since student learning is a dynamic process, both student characterization and the suggested exercises are expected to evolve over time. Hence, this assignation process will be repeated again and again.

An alternative solution is to increase the amount of time in laboratory practice with the professor present. That way, the professor could control the student's interaction with Scratch. However, we believe that this would put too much emphasis on formal learning, which contradicts our education goals. Thus, the challenge is how to improve the current approach with the least level of professor intervention possible. More specifically, it is important to find solutions to the issues with the current approach while maintaining the benefits of employed learning approaches.

With that in mind, a modification is therefore depicted (see Fig. 3b): it's a simple Web Application composed of Scratch as a project editor along with an RS of exercises. Notice that this proposal not only allows the interactions of the current approach, but also personalizes the learning process of students using Scratch. In this way, the professor is able to control students' learning process by creating exercises and including them in the system. Furthermore, students have the opportunity to assess the exercises in order to inform the system of their personal preferences. Using this information, the system suggests new exercises to the student, under the assumption that students with similar tastes and complexity perceptions about exercises are a good source for recommendations.

From a pedagogical perspective, we consider this proposal to be a new mediator between professors and students. In the following sections, the proposal is presented in detail. First, the developed Web Application is described through its main modules and features. Then, the technical aspects of the implemented RS are explained.

4.1 Web Application

The Web Application has an easy-to-use graphic user interface (GUI), and was developed using PHP and MySQL server as a database system.

In Fig. 4, you can see that in the central zone of the application's main window, Scratch is embedded as an editor, while in the upper and right zones the rest of the added modules appear. In the upper zone, the user area provides functionalities in terms of user access to the system. The user interface for the exercise RS appears in the right area of the screen. This module, from top to bottom, consists of:

- a clock for measuring how much time the student spent on the exercise
- the exercise statement
- a pool of recommended exercises
- a pool of all available exercises
- a system for evaluating the taste and complexity of the active exercise.

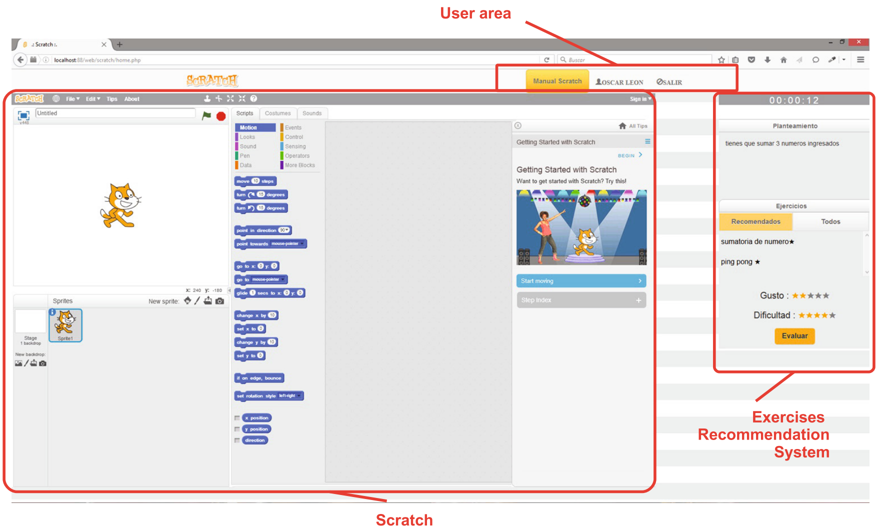

Fig. 4. Main screen of the proposed Web Application.

The main workflow of the interaction between the student and the proposed system is also depicted in Fig. 5. You can see that, after login, the system checks whether the student has previously seen an exercise. If the student has, then 10 exercises are recommended following a collaborative filtering approach. Otherwise, the system selects the easiest and most tasteful exercises among all available exercises. Regardless, the system builds a list of 10 exercises that are presented to the student.

The rest of the steps are easy to understand by following the diagram. However, it is important to note that, after submitting the exercise evaluation, the system applies a collaborative filtering in order to provide a new pool of recommended exercises to the student. Consequently, the student may face different exercises according to their individual experience.

4.2 Technical Aspects of the Recommender System

The RS included in our Web Application is based on a collaborative filtering approach, using both users and items (Bobadilla et al. 2013; Lu et al. 2015). Evidently, in this context, the users are the students, while the items are the exercises to solve in Scratch. The aim of this RS is to exploit the experience of existing students in order to suggest suitable exercises to a certain student. In what follows we refer such a student as *active student*.

Formally, we assume that we have a set of n students $\{u_1, u_2, u_3, ..., u_n\}$ and a set of m exercises $\{e_1, e_2, e_3, ..., e_m\}$, with each student assessing an exercise according to the following two criteria:

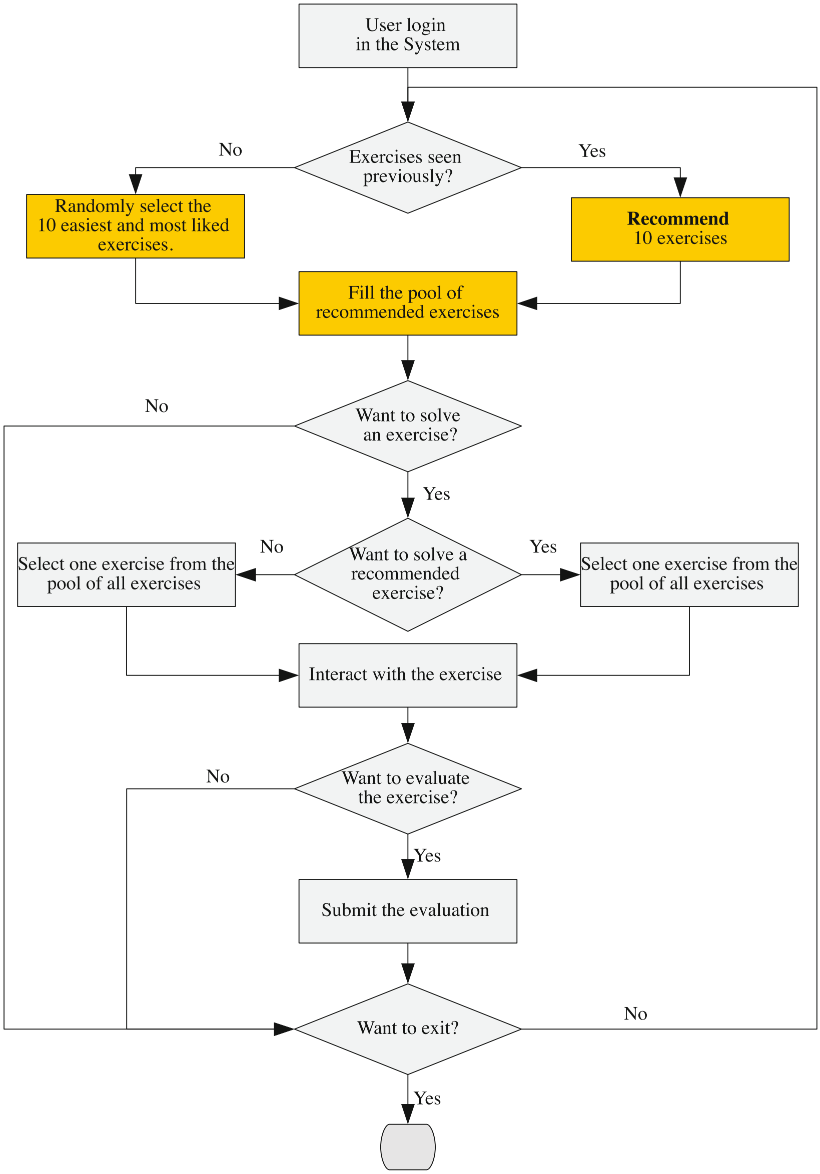

Fig. 5. Main flow of the proposed Web Application.

1. *Taste* ($I \in \{1, 2, 3, 4, 5\}$). It measures how interesting the student found the exercise. A value close to 1 means that the exercise is not interesting at all for the student, while a value of 5 means the opposite.

2. *Complexity* ($C \in \{1, 2, 3\}$). It allows stating the complexity level of the exercise from the student point of view. For this variable, 1 means a low complexity, 2 a medium complexity, and 3 a high complexity.

In this way, each student will have a record of viewed exercises along with their corresponding evaluations. Then, by using this record, the goal is to determine which students have common exercises and an evaluation that's similar to a given student. Once this first filter is applied, the next step is to recommend the exercises evaluated by other students and not viewed by the active student yet. Such a recommendation system involves the following processes:

4.2.1 Cold Start

During the implementation of an RS in real environments a common difficult is how to recommends when no user experience or data exist. This issue is known as *Cold start* (Herlocker et al. 2004). In the case of our RS, we have two scenarios:

1. *the system hasn't any recorded user experience.* In this case, a random set of exercises is proposed to the active student from the pool of all available exercises; and
2. *the active student hasn't any experience recorded by the system.* This is the case of new users. Here, the system recommends exercises that are most frequently evaluated by the community with $I = 3$ and $C = 1$. This assures that new users start with the most popular and easiest exercises.

4.2.2 Neighborhood Computation

A user-user collaborative filtering approach is adopted here. As mentioned before, the first step consists of finding the students who are most similar with respect to the active user k. To this end, the Cosine similarity function between two vectors (Bramer 2013) was considered. These vectors contain evaluations made by two students with common exercises, according to a certain criteria (e.g., taste or complexity). This measure is applied to each evaluation criteria independently.

More formally, $V \in \{I, C\}$ is an evaluation criteria, and $\mathbf{v}_k$ and $\mathbf{v}_i$ the evaluation vectors for the exercises that the active student u_k and the student u_i have in common, respectively. Thus, the similarity between students u_k and u_i is computed as:

$$S_V(u_k, u_i) = \frac{\mathbf{v}_k \cdot \mathbf{v}_i}{\|\mathbf{v}_k\| \cdot \|\mathbf{v}_i\|} \quad (1)$$

S_V takes values in the range $[0, 1]$. A value closer to 1 means a high similarity between the students, while a value closer to 0 means the opposite.

It is important to highlight that Eq. 1 is not able to express the significance of the number of common exercises with respect to the record of all exercises. In other words, since Eq. 1 computes similarity by using information from the exercises that both students have in common, it does not take into account their corresponding records of exercises. We argue that this information is crucial for obtaining a suitable computing of similarity between two given students. In this regard, the following expression was employed:

$$S_P(u_k, u_i) = \frac{|H_k \cap H_i|}{|H_k|} \tag{2}$$

here, H_k and H_i are the sets of exercises seen by students u_k and u_i respectively. It is easy to note that Eq. 2 quantifies the significance of the number of exercises that the active user k has in common with user i by computing the percentage of common exercises regarding the record of the active user. This expression is defined also in the range $[0, 1]$, with possible values the same meaning as Eq. 1.

So we have three sources for computing similarity for every pair of students: S_i, S_v, and S_p. The question is how to aggregate them in order to obtain a single value for the overall similarity. Several alternatives exist to deal with this. For instance, an average or weighted sum of the three similarity values could be used. Another approach is to multiply them:

$$S(u_k, u_i) = S_I(u_k, u_i) \cdot S_C(u_k, u_i) \cdot S_P(u_k, u_i) \tag{3}$$

here, S_I and S_C are defined by Eq. 1, while S_P is given by Eq. 2. Notice that since S_I, S_C and S_P take values in $[0, 1]$, then S will also take values in this range.

The final step after computing similarity with Eq. 3 is to sort the students according to their corresponding similarity values regarding the active user k. This sorting operation is performed in descending order involving students with $S > 0$. The obtained set of sorted students is denoted by U_k.

4.2.3 Building the List of Recommended Exercises

In this process, a list of exercises recommended for the active user u_k is created by iteration through U_k. Specifically, for each student of the U_k set, exercises not evaluated by the active user are added to the list. This process runs until the list is completed with 10 exercises, or no more students from U_k remain to be analyzed. In this latter case, the list is completed with the exercises that the community more frequently evaluates, but not previously evaluated by the active user.

5 Preliminary Results

Evaluating RSs in educational environments is an ongoing research topic. It is indeed a complex process because it involves several goals that are hard to assess (e.g., knowledge acquired by the student and user satisfaction, among others). These evaluation goals can be grouped into three broad categories: *RS performance*, *user-centric effects* and *learning effects* (Erdt et al. 2015).

Due to the characteristics of our educational environment and the relative short time of use of the proposed system, a *Real-Life Testing* methodology was adopted (Erdt et al. 2015). Its main goal is to assess the system according to perceived satisfaction of real users (i.e., the students).

A total of 64 students from both Computer Science and Industrial Engineering participated in the analysis. Both of these areas of study include the Fundamentals of Computer Programming course in their curricula. However, more motivation was expected of Computer Science students than of the Industrial Engineering students. Such a difference can be useful for assessing the system from two distinct viewpoints.

After using the system over a period of three months, we gave the students a questionnaire asking their opinion of nine assertions. Table 1 shows these assertions according to the above-mentioned three evaluation goals (Erdt et al. 2015). More emphasis was put on evaluating both learning and user-centric effects (e.g., more assertions are included for assessing these goals). In this context, they seem to be more valuable criteria than the RS performance since:

1. it is difficult to assess accuracy in the presented RS if no data are available for conducting offline experiments; and
2. the system will take no more than 100 users; consequently, when users are accessing the Web Application, it's expected there will be no system overload. In addition, for that number of users the similarity computations and the sorting operation explained in the previous section can be performed in an efficient manner.

Table 1. List of assertions employed in the questionnaires for assessing the proposed system.

Evaluation Goal	Code	Assertion
RS performance	A1	Scratch+ERS recommends to me exercises according to my skills in computer programming
	A2	The interaction with Scratch+ERS is fast enough.
User-centric effects	A3	I believe that *taste* and *complexity* are not only simple but effective criteria for evaluating the exercises I faced
	A4	Scratch+ERS presents a comfortable graphical user interface and navigation
	A5	I consider that Scratch+ERS to be a different but better system than the Scratch without recommendations.
Effects of learning	A6	I have more chance of being promoted if I use the Scratch+ERS application
	A7	I believe that the Scratch+ERS will help to improve my academic performance in the subject Fundamentals of Computer Programming
	A8	Scratch+ESR helps to personalize my learning in computer programming
	A9	I think that by using Scratch+ERS I have improved my autonomous learning

However, two assertions related to the accuracy and response time of the system have been included (e.g., assertions A1 and A2). It is clear that both are less precise than those obtained from an offline experiment, since they were measured based on opinions of real users. However, the authors are aware that a greater number of technical tests will be needed, which will be the subject of future works.

The nine exposed assertions were responded to using one of these five levels: *strongly agree*, *agree*, *neither agree nor disagree*, *disagree*, and *strongly disagree*.

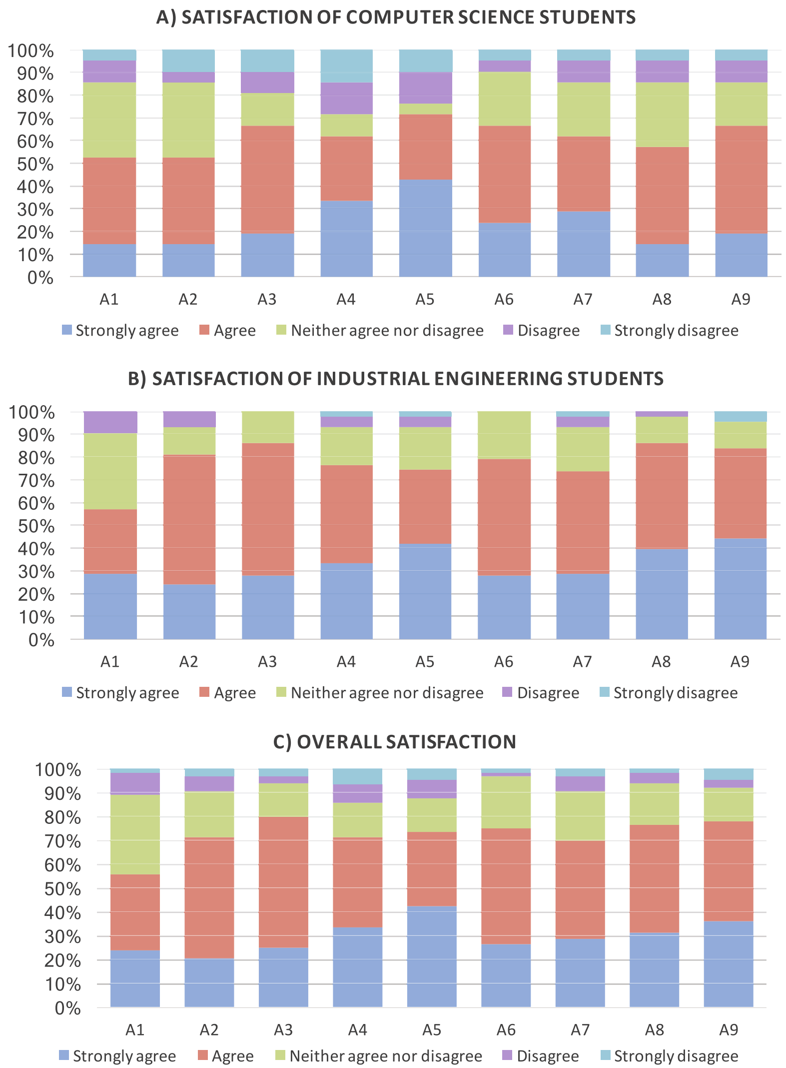

Fig. 6. Satisfaction of students with the system according to the questions.

The results of the questionnaires (Fig. 6) were organized into three groups: (a) Satisfaction of Computer Science students, (b) Satisfaction of Industrial Engineering students and (c) Overall satisfaction. The latter is the aggregation of the first two groups. A generally acceptable degree of satisfaction is appreciated. For example, more than 50% of the students at least agreed with all the assertions.

However, differences exist between the first two groups. As expected, Computer Science students are more critical than Industrial Engineering students (Fig. 6a and b). In both cases, a significant number of students do not agree with A1, indicating that much more work has to be done regarding the system's accuracy. A similar conclusion can be derived from the system time response (A2).

As for the user-centric assertions (A3, A4, and A5), more than 60% of the students from both careers at least agree, and 40% strongly agree with assertion A5: that the proposed system is better.

Finally, regarding the assertions for evaluating the learning effects (A6, A7, A8, and A9), a clear difference exists between both areas of study. For instance, about 60% of Computer Science students agree with those indicators, while 75% of Industrial Engineering students agree.

In general, there was a suitable satisfaction level from the students of the proposed system (Fig. 6c).

6 Conclusion and Future Work

In this chapter, an integrated approach for improving computer programming students' learning process with Scratch is proposed. Our previous experience regarding the use of Scratch for complementing the teaching process of Foundation of Computer Programming at Universidad Estatal de Milagro, Ecuador, provides important evidence that such a learning strategy can be improved. Specifically, for solving two issues: (1) the current gap between the formal and informal learning approach and (2) a personalized interaction between the student and Scratch.

An easy-to-use Web Application was therefore developed that involves Scratch along with a recommender system for exercises. A Real-Life Testing methodology was adopted in order to validate this approach. Students were asked to assess nine indicators regarding three goal areas: (1) recommender system performance; (2) user-centric effects; and (3) learning effects. In general, a significant level of satisfaction among the students was observed.

However, this is considered to be a first step towards having a better system. Future works will be oriented to improve both, the recommender system performance and Web Application usability. Besides, we will explore the inclusion of our proposal into the Scratch source code with aims of sharing its benefits with the existing community.

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An International Study of Faculty Perceptions on Communication Development in Engineering Education

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Abstract. It is crucial for engineers to communicate effectively in a variety of settings as globally competent engineering leaders in our modern workforce. To prepare globally competent engineers, higher education must continue to reconceptualize curricula and pedagogy to meet industry and social needs. This international survey of engineering faculty and deans includes participants from multiple universities as well as members of the Global Engineering Deans Council and International Federation of Engineering Education Society. Our research provides insight on perceptions of faculty and deans about aspects of developing globally competent engineers through communication development. This study reports the amount of value that faculty and deans place on types of communication, compares their confidence levels in teaching and assessing communication, represents where and how often, if at all, communication curricula integration is needed in engineering programs, and the communication skills engineers need.

Keywords: Faculty · Communication · Confidence · Teaching · Assessment · Mixed-methods

1 Background

Pressing social and economic needs call for engineering schools and departments to produce diverse leaders who can create innovative solutions to the world's most difficult problems. The challenges that must be addressed by the next generation of engineers are becoming increasingly complex as society continues to grow more interconnected [1–5]. To be effective engineering leaders in a global workforce, engineers need strong communication skills that will allow them to interact with a wide-ranging audience, including entrepreneurs, policy makers, community leaders, and the general public—most of whom do not necessarily have a background in engineering, science, and technology.

Our research aligns with one of the key recommendation from leading reports on engineering from around the globe – develop engineers who can communicate effectively. That common theme resonates across leading international research that includes: *The Engineer of 2020,* reports from Enhancing Engineering Education in Europe, Iberoamerican Engineers Leadership Attributes, and the Global Summits co-hosted by

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the Chinese Academy of Engineering, National Academy of Engineering, and Royal Academy of Engineering. These international thought leaders posit a common theme: develop engineers whose communication skills will allow them to become successful professionals and, who, in turn, will drive technological and social change [3–6].

The *Engineer of 2020* study was developed in two phases. In the first phase the goals were to develop possible scenarios of what the world would look like in 2020 and then determine the skills necessary for engineers to contribute productively in the world [7]. The first phase noted the globalization of industry and engineering practice, the growing share of engineering employment in non-traditional, less technical engineering work, the shift to a knowledge based service economy, and increasing opportunities for using technology in the education and work of engineers. The *Engineer of 2020* identified that one of the main attributes of a successful engineer is to have good communication skills with multiple stakeholders.

European engineering educators were recently grappling with the challenge that mobility posed to both country-based engineering education systems and common European engineering competencies [8]. In response, there was a new thematic network established called the Enhancing Engineering Education in Europe (E4) who set initiatives that align with aspects of the *Engineer of 2020.* The E4 framework aimed to foster engineering education where graduates should be able to work in cooperation with engineers and non-engineers. Furthermore, and most strongly aligned with *Engineer of 2020*, is the goal that engineering graduates should develop competencies in teamwork and communication.

Engineering educators from different Latin American regional organizations formed an executive committee about the Iberoamerican Engineer and identified criteria, that upon reflection is in conjunction with *Engineer of 2020*, that engineers should have: (a) knowledge of another foreign language; (b) the capacity to adapt to other countries; and (c) the ability to communicate, work in teams, be creative, entrepreneurial, and innovative [9].

Recently, over 450 engineering leaders, educators, and policy makers attended the inaugural Global Grand Challenges Summit [10]. The mission of the Summit was "With the prosperity of future generations relying on unprecedented levels of interdisciplinary and international cooperation in pursuit of solutions to the world's most pressing challenges, the Summit, organized by the Royal Academy of Engineering in partnership with the US National Academy of Engineering and the Chinese Academy of Engineering, sought to provide a new global platform for the world's leading thinkers to share their ideas with the next generation of engineers on how to develop the international frameworks, tools, and collaborations needed to solve our common issues." The point is that preparing engineers to be globally competent is indeed a worldwide initiative.

We examine how engineering schools are helping students develop four key communication competencies: (1) writing, (2) creating and delivering presentations, (3) developing and employing visual literacy skills, and (4) participating in teams. The Organization for Economic Co-operation and Development's (OECD) *Definition and Selection of Competencies (DeSeCo) Project* describes "competency" as:

> …more than just knowledge and skills. It involves the ability to meet complex demands, by drawing on and mobilizing psychosocial resources (including skills and attitudes) in a particular context. For example, the ability to communicate effectively is a competency that may draw on an individual's knowledge of language, practical IT skills and attitudes towards those with whom he or she is communicating [11].

Broadly, the aims of our overall study are to investigate communication development in undergraduate engineering programs from the perspectives of the faculty and deans, engineering students' perceptions of their self-efficacy as communicators, and observations of communication capabilities exhibited in engineering programs.

This paper focuses on the faculty and deans' survey to illuminate perspectives on communication curricula for engineering education, confidence in teaching and assessing communication, and the communication skills engineers need in this modern era. In another paper, we will report on the students' perceptions of their self-efficacy in communication as well as do direct assessment of their communication ability.

2 Methods

We hypothesize that engineering deans and faculty will report different levels of value in teaching communication capabilities to undergraduate engineering students, have differences in their confidence levels of teaching communication compared to assessing communication, and differences in their beliefs about communication curricula integration in engineering courses. Our specific research questions that guided this portion of the overall communication development study (i.e., the deans and faculty survey) are:

a. Where and how often do deans and faculty report that communication should (if at all) be taught to undergraduate engineering students?
b. What do deans and faculty report are the most important communication skills that engineers need and use?
c. Do deans and faculty place different levels of value on teaching communication and if so, how do the values compare across four types of communication (oral presentation, writing, visual literacy, and teamwork)?
d. How do the reported confidence levels of teaching and assessing communication skills of deans and faculty compare across four types of communication (oral presentation, writing, visual literacy, and teamwork)?
e. How do the reported confidence levels from deans and faculty compare between teaching and assessing four types of communication (oral presentation, writing, visual literacy, and teamwork)?

To answer these questions, we have collected multiple forms of data including surveys, observations, and work products. Over the last two years, we have set the foundation for an interdisciplinary, inter-institutional, cross-cultural study of the teaching and learning of communication at four partner institutions for case studies and scaled the data collection globally with a survey of the Global Engineering Deans Council, the International Federation of Engineering Education Societies, and the Student Platform for Engineering Education Development. This paper describes the survey of faculty and deans that complements the in-depth case studies of students and faculty in four universities in Asia and in the United States.

2.1 Demographics of Deans and Faculty Survey

There is a diverse representation of engineering deans and faculty in the N = 126 survey respondents in regards to their amount of years as a faculty member, their first language, and their identified gender. The two largest percentages of respondents have been teaching less than five years and over sixteen years respectively (Fig. 1). English and Farsi are identified as the highest percentages of first languages spoken by the participants. Other first languages included: Turkish, Polish, Spanish, Hungarian,

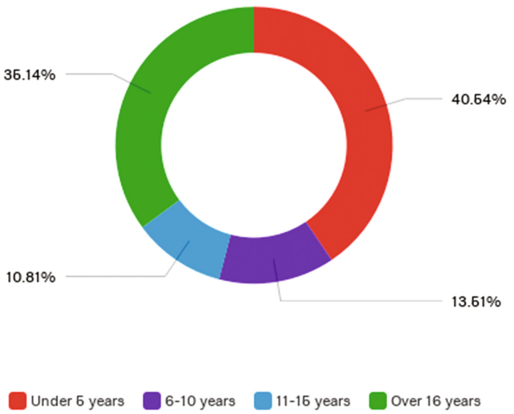

Fig. 1. Years as engineering faculty

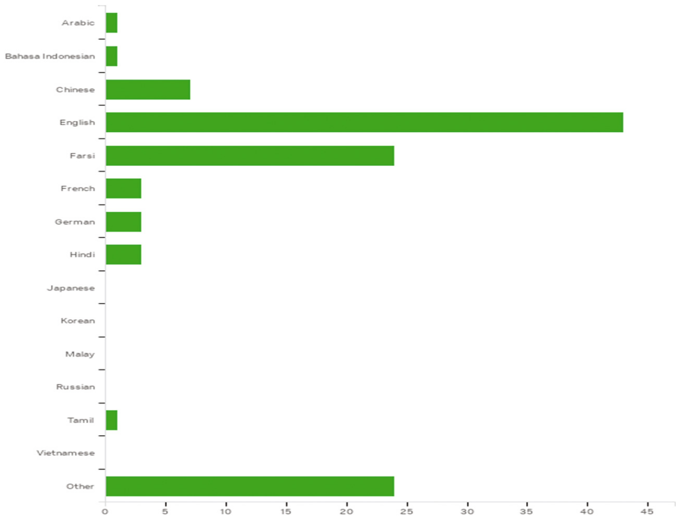

Fig. 2. First language/native tongue

Hebrew, Sinhalese, Greek, Portuguese, Italian, and Swedish (Fig. 2). The gender demographics of this survey group is similar to a vast majority of engineering colleges in that 12% identify as female and 88% identify as male.

3 Results

This paper focuses on the results of a global survey of deans and faculty from undergraduate engineering programs about perceptions of four types of communication – oral presentation, writing, visual literacy, and teamwork. We explore the value they place on teaching four types of communication to engineering students, their confidence in teaching and assessing each of these types of communication, where and the amount of time that should be dedicated to communication curricula in an undergraduate engineering program, and the most needed communication skills for engineers in the global workforce.

In analyzing the survey results, we observe that deans and faculty find all four communication types to be extremely valuable to teach engineering students. We note that the large majority of the survey respondents believe that communication curricula should be taught within engineering courses yet there is not a consensus as to what percentage of time should be dedicated to communication development. We are able to see that the survey participants have varying rates of confidence in teaching and assessing communication in each of the four communication areas. We then divide the participants into subgroups for deeper analysis of teaching and assessment. We are able to identify differences in confidence levels of teaching and assessing based on the

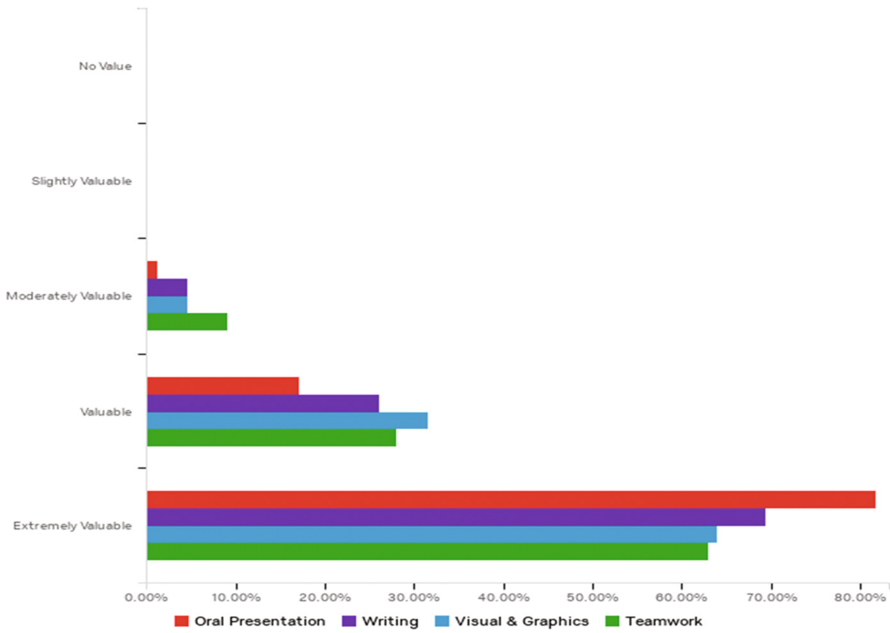

Fig. 3. Faculty rated value of teaching 4 types of communication skills to undergraduate engineering students

amount of years that the respondent has been a faculty member. We use T-tests to determine if the comparisons of the percentages in our data were significant. The following comparisons have a low P-value ($p < .1$) so that we have a 90% confidence rate that there are statistical significances between findings. Specifics about each of the findings are described in more detail below.

The results show that oral presentation and writing are the most valuable communication skills to teach students (Fig. 3). The data show that more than 60% of all respondents believe that each of the four communication types are extremely valuable to teach undergraduate engineering students. No one rated communication as slightly valuable or of no value.

Given the value that faculty placed on teaching communication skills to undergraduate engineering students, it is also important to understand where and how often these skills should be taught. We are curious about faculty perceptions of where communication should be taught whether within engineering courses, in separate courses in communication, within co-curricular activities, or perhaps that communication skills should not be developed in engineering students. From our overall population of engineering deans and faculty, 72% indicate that they believe communication skills should be developed within engineering courses. Approximately 17% believe those skills should be taught in separate communication courses, 8% stated that they should be developed within co-curricular activities, and 2% did not think that communication skills need to be developed in engineering students (Fig. 4).

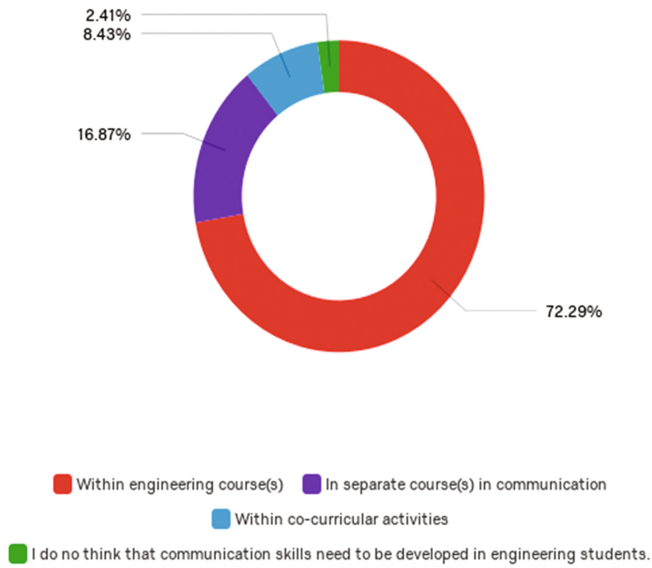

Fig. 4. Faculty belief of where communication skills should (or should not) best be taught to undergraduate engineering students

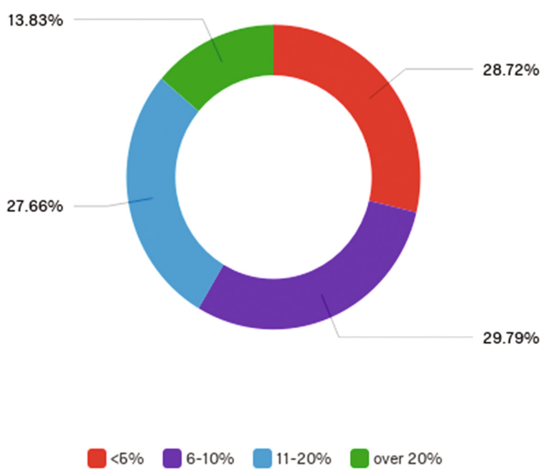

Fig. 5. Faculty belief in the amount of time that should be dedicated to communication development in undergraduate engineering courses

After learning about where, if at all, communication development should take place in engineering education programs, it is meaningful to learn how much course time should be dedicated to communication curricula. There is a fairly even distribution in results that faculty believe communication curricula should be embedded <5% of the course (29%), 6–10% of the course (30%), and 11–20% of the course (28%). Approximately 14% of the faculty believe that communication curricula should be integrated into more than 20% of the engineering courses (Fig. 5).

In addition to wanting to know the perceived value of the four communication types, we also want to understand the confidence levels of teaching and assessing those communication skills. The survey data provide ways that we can understand the confidence levels, compare confidence levels across types of communication, and explore the differences in confidence teaching and assessing.

As the emphasis on communication for engineering students was ramped up by the *Engineer of 2020* in 2005, is helpful to disaggregate the data to compare early career (10 years or less teaching engineering) to later career (more than 11 years teaching engineering) faculty and deans when analyzing results about confidence in teaching and assessing communication skills. When the data are disaggregated, we are able to compare results between early career and later career faculty in a variety of ways. The disaggregated data analysis provides insights into differences in: (a) confidence in teaching and assessing each of the four communication types; (b) confidence between teaching and assessing; and c) confidence levels between early career and later career engineering faculty.

One of the notable comparisons between teaching various communication types is between oral presentation and teamwork. The early career faculty report that 56% are extremely confident in teaching oral presentation skills in contrast to a significantly fewer amount, specifically only 19% of early faculty, who indicate that they are extremely confident in teaching teamwork. The survey results indicate that 56% early

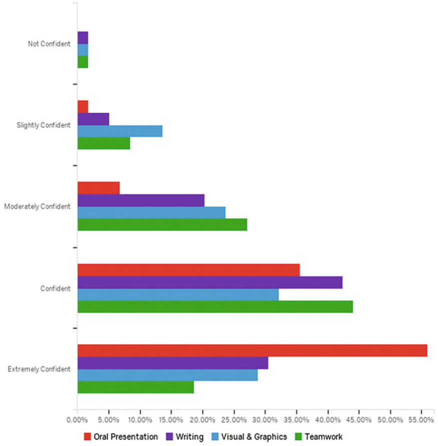

Fig. 6. Early career faculty rated confidence level in TEACHING

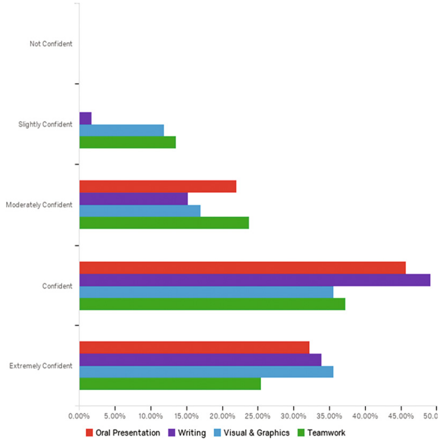

Fig. 7. Early career faculty rated confidence level in ASSESSING

career faculty are extremely confident in teaching oral presentation skills compared to only 32% of those same respondents being extremely confident in assessing oral presentation skills (Figs. 6 and 7).

In later career faculty, we also see differences between confidence levels in teaching and assessing communication skills. The differences in teaching and assessing for this population are inverse to the early career population. Whereas the early career faculty report a higher level of confidence in teaching than in assessing communication skills, the later career faculty report a higher level of confidence in assessing those skills in comparison to teaching the skills. For example, data from the later career respondents show that 33% are extremely confident in teaching oral presentation skills yet 47% rate

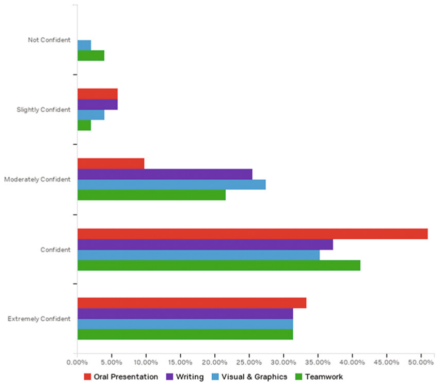

Fig. 8. Later career faculty rated confidence level in TEACHING

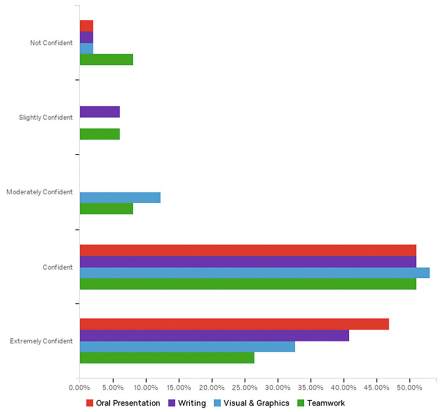

Fig. 9. Later career faculty rated confidence level in ASSESSING

extreme confidence in assessing oral presentations. Similar trends are also identified in comparing teaching and assessing of writing skills when this group of faculty report 32% feel extremely confident in teaching while 41% are extremely confident in assessing those same writing skills (Figs. 8 and 9).

In addition to the T-tests to compare the confidence levels between teaching and assessing communication skills within each subgroup of faculty based on their years of teaching, we use cross tabulation to compare results between faculty levels in each of the communication types. In conducting the data analysis, we conducted chi-square tests to determine if there were significant differences between the levels of confidence in teaching and in assessing communication in each of the four communication types based on the amount of years as a faculty member. The chi-square tests performed indicate that there are significant differences between the confidence levels based on the amount of years as a faculty member. When performing the chi-square test for this data set of confidence level in each of the four communication types, there are twelve degrees of freedom based on the possible categories. The chi-square tests reveal that there is a relationship between years of being an engineering faculty member and confidence in teaching and assessing communication in almost all areas of communication except for assessing visual literacy and teamwork where the *p*-values are too high to be considered significant (Table 1).

Table 1. Chi-Square analysis between early and later career faculty confidence in teaching communication and assessing communication

Confidence in teaching and assessing communication type	P-value
Teaching oral presentation	.019
Teaching writing	.1
Teaching visual literacy	.08
Teaching teamwork	.05
Assessing oral presentation	.001
Assessing writing	.039
Assessing visual literacy	.24*
Assessing teamwork	.17*

*indicates *p*-values that are not significant

We are also curious about deans' and faculty perspectives in their own words about what they consider the most important communication skills for engineers to have and use in the modern workforce. We use NVivo software to analyze these qualitative results of the entire population of faculty and deans surveyed. We analyze their responses for frequency and represent them in the following word cloud (Fig. 10). From these qualitative data, we are able to see that oral presentation, writing, and sharing technical information are identified as being the most important communication skills for engineers. In addition to the frequency of qualitative results, we coded the data to identity key themes that arise from the deans and faculty. Some of the main themes are that engineers need to clearly share information using non-technical jargon and effectively use the other communication types (visual/graphic and teamwork). Data also indicate the importance of empathizing with diverse stakeholders and to have negotiating skills.

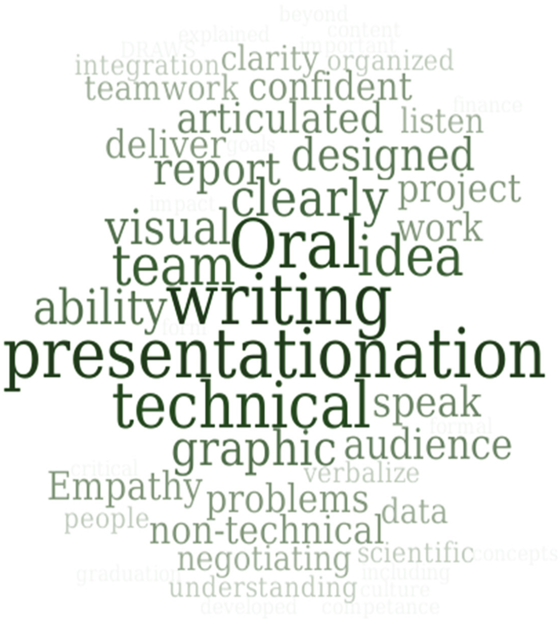

Fig. 10. Qualitative themes about the communication skills engineers need and use

4 Discussion

These surveys have allowed us to see faculty and deans' perceptions of the value of communication development in engineers, where and how much communication curricular integration should be part of undergraduate engineering education, how confident they are in their ability to teach and assess four types of communication skills, and in the overall communication skills that engineers need in our global market. These data give us insights into when and how often we can recommend curricular integration to teach and assess communication competencies and also indications of ways we can support strengthening pedagogy in communication areas that respondents indicated less confidence in teaching and assessing.

From our diverse population of deans and faculty of undergraduate engineering programs, we report that it is important and valuable to develop communication skills to be a successful engineer. Their perspectives align with the broader, worldwide reports that were included in the literature review of this paper that focus on the educational initiatives to develop globally competent engineers who are effective communicators.

Although the large majority of the deans and faculty reveal that communication skills should be developed within engineering courses, there are mixed sentiments about how much course time should be allotted to teaching and assessing those skills. The population surveyed are fairly split between spending <5%, 6–10%, and 11–20% of course time on communication curricula. As we continue the overall study, we are conducting a curricular review to explore how communication is taught and assessed as well as how much of the course is actually dedicated to the development of these skills.

This complementary part of the overall study may help us to learn more about these data results. For example, we may find that there are particular courses that lend themselves to having 11–20% communication curricula integration where as in other types of engineering courses, it may be a better curricular design to include communication development but to a less degree.

We chose to disaggregate data so that we could understand more about aspects of confidence in teaching and assessment that may help in professional development and mentoring. We explored the survey population within the subgroups of early career (<10 years teaching) and later career (11+ years teaching) faculty and deans. Disaggregating the data provided the opportunity to see trends in the types of communication that each subgroup is confident (or not) in teaching and assessing. It further demonstrated differences between subgroups in their confidence levels in each of the four types of communication and between teaching and assessing. It is interesting to note that the early career faculty report much higher confidence in teaching communication as compared to assessing those skills and conversely, later career faculty report higher confidence in assessing than in teaching communication to undergraduate engineers. The survey data reveal that oral presentation is the type of communication that faculty are most confident in teaching and assessing and teamwork tends to be the area of least confidence.

These data can aid in content for professional development, curricular design, and pedagogy support. It can also be a springboard for two-way mentoring and co-teaching. Since visual literacy skills and teamwork are areas where faculty and deans show a lower level of confidence yet are perceived as being important for engineers to develop, there are opportunities to support curricular and pedagogical design to improve these areas of engineering education. We see that there are clear differences between the early faculty feeling more confident in teaching communication than their later career faculty counterparts. Meanwhile, the later career faculty are more confident in assessing communication than their early career peers. These differences can be seen as strengths in developing effective, symbiotic two-way mentorship where each person is bringing a strength and area of growth into the relationship. These are also opportunities to do course design where an early and later career faculty can co-teach together.

Finally, we see that our diverse survey respondents are indeed voicing the same sentiments reported in the worldwide initiatives in engineering education that state our engineers need to graduate with a wide range of skills to be effective within technical settings and also in collaborating with stakeholders who may not have backgrounds in the sciences and engineering fields.

5 Conclusion

It is crucial for engineers to communicate effectively in a variety of settings as globally competent engineering leaders in our modern workforce. To prepare globally competent engineers, higher education must continue to reconceptualize curricula and pedagogy to meet industry and social needs. Deans and faculty of undergraduate engineering programs from around the world believe that there is a high value in communication development their students and the majority believe that it should happen within engineering courses. Since there are different perspectives on the amount of communication curricula should be included within engineering courses, we can look to successful university models such as ones that offer communications-intensive courses within each major and include a wide variety of communication activities embedded into engineering courses across multiple semesters. There are also differences in the confidence levels between teaching and assessing the four types of communication including in comparing confidence between early and later career faculty. In addition to professional development in communication skills and two-way mentoring, we recommend looking again to successful university models where they use co-teaching pedagogy so that engineering faculty and communications experts collaborate on curricular design, instruction, and assessment. From this research, we are able to see positive trends in perspectives, curricular commitment, and confidence in communication development from engineering deans and faculty, which then supports the notion that engineering education programs are addressing the multiple reports from global thought leaders on ways that engineering education needs to improve for our future engineers to be successful.

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French Engineering Universities: How They Deal with Entrepreneurship and Innovation

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Abstract. Innovation and entrepreneurship, which are sometimes linked in pedagogic considerations, especially in France, are points where French education is not good enough for the time being; many attempts have been realized since 30 years to improve the skills of our graduates in this field and however these attempts were not often very fruitful. With the development of Horizon 2020, European governments try to imagine new solutions to reach their goals and it is also the case in France.

The French Ministry for Education and Research has launched a call for projects named PEPITE so as to develop Innovation amongst the students and particularly amongst the engineers. Accreditation agencies also cooperate in this direction because their members think that innovation is at the heart of economic development.

This chapter compares the manner that European (and more specifically Belgium ones) and French engineering higher education institutions, among them Polytech Orleans, answered to the call of Horizon 2020 and develop strategies to increase innovation and entrepreneurship in Europe.

Keywords: Innovation · Entrepreneurship · Fablab · PEPITE

1 Introduction

In France, many engineers recently graduated do not have the wish and even the idea to create new activities. One of the reasons is that it is very easy for engineers to get a job in great companies in Western Europe, but another reason is that risk's culture is not very developed all along education. The French government, aware of those facts as all European governments decided to create opportunities for Higher Education Institutions (HEI) so as to help them, first, to convince their students of the interest to create companies but also, to educate them for this new challenge. Among all those opportunities, a HEI can choose the more pertinent strategy as a function of its size and territory.

However, this entrepreneurship process cannot only start at the higher education level that is why it is necessary to initiate the work with high schools so as to create a global frame where innovation and entrepreneurship could develop further.

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2 The Landscape of Education to Innovation and Entrepreneurship in France and Around France

The aim of governments is to realize the project they have for many years (from the 80's!) which is to push young people, in all branches of economy, to innovate inside companies or to create a new company or both.

It concerns as well high schools as higher education with a common objective of employability. EU has published a specific report [1] on these matters and, studying this document, we see that the problem is nearly the same in many European countries, EU needs and hopes to share good practices on the subject.

The main findings of this report are the global share of entrepreneurship as a key competence through Europe and the need to develop entrepreneurial skills of young people [2]. However, the need to develop those skills reveals through signs of emerging trends towards broader innovation strategies.

Stable and comprehensive funding streams still need to be developed for those activities and there are few or no guidelines for teaching methods concerning innovation; very few countries include practical entrepreneurial experience as a regular and compulsory part of the curriculum: in France for example "Entreprendre pour Apprendre" which takes place in high schools is not mandatory and it depends very much on the goodwill of teachers.

So, learning outcomes linked to entrepreneurship education are fragmented in most European countries: they are not comprehensive and lack progression between education levels.

In France the PEPITE device tries to cope with some of these problems for higher education, it is dedicated to all kinds of HEIs. PEPITE that exists at national level is also defined in each territory.

2.1 The Device PEPITE France

The more visible issue, which is common to all French HEIs, is this new status created in 2014 for students that together with their studies can engage in the creation of a new company [3]: they can elaborate a real project, becoming in such a way both students and managers. Together with preparing their diploma such students get the opportunity to work on their own project instead of making an internship and they are coached by specific tutors (both academic and professional ones).

Most of French Engineering Universities developed such an opportunity for their students and it seems to become successful.

- According to the recommendation of EU, the first aim of PEPITE France was the information, communication and awareness of both young people, teachers and civil society. PEPITE decided to use the innovative means of communication that young people uses to better communicate with them: new numeric tools and books, realization of short videos [4], creation of a module dedicated to make future teachers of high school and higher education aware of entrepreneurship.

- The second level of objectives aims at the creation of a new framework of entrepreneurial skills fitted to the different levels from high school to PhD degree level and the realization of a numeric tool dedicated to the measure and validation of certified skills in entrepreneurship and innovation.
- The third level concerns the “passage à l’acte”: the national status of “Etudiants – Entrepreneur” had to be reinforced through the creation of a network including both students and structures that could coach and finance them.
- The last level to be realized is the measure of impact of the previous actions; it is necessary to create a culture of results and to define indicators, which was not the case in the previous campaigns. An observatory of usages will be created so as to evaluate the efficiency of the different actions.

In France 29 local PEPITE devices have been created. PEPITE is a word which means at the same time “Pôles Étudiants Pour l’Innovation, le Transfert et l’Entrepreneuriat” and (gold) nugget: this mean that the ministry bets very much on these new innovators!

Amongst the students using the PEPITE devices there are many students wishing to become engineers: there have many advantages to become “students-entrepreneurs” such as:

- Being accompanied and counselled both by a teacher and a referent external to the institution but belonging to the network of PEPITE (manager of a company, business angel…).
- The possibility to access the co-working place of PEPITE or of one of its partners, so as to be able to create a network.
- The possibility to obtain a specific contract with a structure where the student can emit invoices without having already created its company (“Couveuse d’Entreprise”).

Where an internship or a project is mandatory during the curricula such as in engineering studies, the student can substitute the entrepreneurial project to a student project or to an internship. The student keeps the benefice of social security coverage and he can access to the grants offered to lower income students.

Launched on September 15th 2014, 1600 students became “Students entrepreneurs” and 2.8 millions of Euros had been spent, which is a bit far from the initial objective: 20000 entrepreneurs in 2017.

French people are observing very closely what happens in the neighboring countries that seem to succeed on innovation and/or entrepreneurship better than us, those countries began working on entrepreneurship and innovation several years before us!

2.2 Innovation and Entrepreneurship Around France

In Belgium and Switzerland, countries that are the neighbors of France, education to innovation and entrepreneurship is more developed and has already a great success; in EPFL (Lausanne) there are many start up and in University of Gent (Belgium) the systems exist since a long time and are fruitful.

The University of Gent is a research driven university of Northern Flanders. It is well known in Belgium but also through the world.

In UGent for example [5], Faculty of Engineering and Architecture (FEA) has an outstanding role in the field of innovation and knowledge transfer. Many start-up companies were built on scientific research of FEA and they continue to collaborate with FEA. To stimulate this transfer of knowledge, UGent has a funding mechanism the IOF (Industrial Research Fund). There are different projects types between pure research and valorization: Concept, Startt, Advanced, and Stepstone. Between 2005 and 2013, FEA staff members were involved in 27 of those projects.

Business development centers headed by a business development manager are the direct contact point for industrial partnerships, they are embedded in the research entities and can detect opportunities at early stages. Many development centers concern the FEA: 42, 1% of the UGent Spin-offs (of a total of 40) originate from the FEA with an average of 3 per year over the past 6 years.

UGent's Tech Transfer supports research staff in identifying funding mechanisms and business opportunities with legal support.

The patent portfolio is quickly increasing: at the end of 2014 it included 88 patents among them 65 were signed in the last five years.

All this activity has consequences for students themselves, who are also encouraged to be entrepreneurs. The name of student-entrepreneurship center is "Durf Ondernemen "which means "dare to be an entrepreneur" [6].

Three levels have been distinguished and actions developed fitted for each level:

- First level is dedicated to "Students with an interest to entrepreneurship", they are offered 4 different kind of courses: the Basic course "Leer Ondernemen" is an elective course in all 2nd year bachelor engineering program. This course if very popular in FEA, in 2015, 263 students of FEA followed it on a total of 428 for the whole university. Introduction to entrepreneurship (including a business game) is an elective course in all master engineering programs. In "Dare to venture" students build a feasibility study and make a business plan. It can be taken in all engineering programs. "Dare to start" is based on the lean start up methodology developed at Stanford University, it is also an elective course in all master engineering programs.

The "Hunch up" test has been developed together with the faculty of psychology to measure entrepreneurial potential of students, it is used in all the entrepreneurial course offer. Extracurricular activities such as "Student Ghentrepreneur" are organized for all the students of Ghent, they allow the mix of the origins of students: the city of Ghent select the yearly "student entrepreneur of the year".

- The second category of students are "Entrepreneurial students": about 100 students are coached each year and they receive a budget of 500 euros.
- The third ones are "Student entrepreneurs", if their company is not yet started the student must have previously gathered 60 ECTS credits to be part of the system: the university expects that first year students focus 100% on their studies. This status offers flexibility to combine studies with running a small business, students have to apply each year: a student must have passed at least 50% of the courses taken the year before to be accepted. The student receives a grant of 1000 €uro per academic year. A spotlight magazine gives publicity to those students and the university tries to become a customer of the students.

In FEA 68 students have been Student Entrepreneurs since 2011, entrepreneurship is very developed in subjects linked to information systems and biomedical sciences; we can notice that after faculty of economies, engineering is the second faculty of UGent for the number of Student entrepreneurs.

"Student – Entrepreneurs" have been created three years before the creation of PEPITE, perhaps it justifies the advance of Gent University?

We also think that researchers are really encouraged to entrepreneurship during their PhD degree and that the example of teachers on students is something important; for the time being, it is not really in the culture of French teachers and researchers.

2.3 Role of the French CTI (Commission des Titres d'Ingénieur)

In France, Engineering education is certified by a specific quality agency (Commission des Titres d'Ingénieur) that realizes each five years an audit of each Engineering University after the redaction of a Self-Evaluation Report by the HEI.

CTI allows the right to the University to deliver the title of "Ingénieur diplômé".

Last year CTI had to define new criteria in accordance with its stakeholders. With the trend concerning the increase of innovation and entrepreneurship, the points concerning innovation and entrepreneurship were much more developed in this new 2016 version of the criteria [7]. Previously, these items were placed inside research and now there is a specific chapter on those points.

CTI queries institution to know if they have adapted their pedagogies so as to encourage innovation: are there experimental practices, is there a creativity exercise and a social and economic evaluation of innovation?

Concerning entrepreneurship, the institution should have at the least put in place awareness measures, and must measure their impact.The role of the local device PEPITE in the institution must be explained too.

The agency is very aware of the importance of innovation and entrepreneurship because it is composed by half of academic people and by half of members of companies that are very concerned by those points.

We will develop at the end of this paper (5) the results that CTI obtained in this field.

3 Some Factors that Help to Increase Innovation and Entrepreneurship in Polytech Orléans

Polytech Orléans is one of the 206 French Higher Education Institutions devoted to engineering education at Master level, it is part of a general university: Université d'Orléans. This means that near Polytech there are students of other disciplines such as law, management, business, design…

But Polytech Orléans also belongs to a strong network of 14 HEIs situated on the whole French territory, this means that the effort made in Orléans are also discussed and shared with other members of this network.

Polytech Orléans is periodically accredited by CTI. Polytech is located near Belgium and Switzerland, so the comparison with those countries' initiatives is important also because those countries are French speaking too.

The devices that Polytech puts in place are more or less characteristic of what French Engineering institutions have developed but they can be more specifically oriented according to the surroundings of the HEI [8].

Polytech Orleans is part of the local PEPITE Centre but many of the devices presented here have been specifically designed by Polytech Orléans.

The responsible of PEPITE in Région Centre is also the dean of Polytech Orléans, this means that perhaps Polytech should be more committed to entrepreneurship than other HEIs.

3.1 Curricula Inside the University of Orléans

The PEPITE device is often not enough to convince students about entrepreneurship, an adequate surrounding must be put in place for students: a specific curriculum can be part of it.

Besides engineering curriculum, Polytech Orléans has created in 2012 a specific post Master "Creation of companies both innovative and socially responsible" [9], that attract many students graduated from a Master degree; Polytech's students can also undertake it. This curriculum gives the student the toolkit to create a company. The curriculum is oriented towards tomorrow companies: innovative and concerned by sustainable development.

During the course, the project of each student is matured and followed by coaches so that at the end of the year the enterprise can be created.

This Master has been created through partnerships with Design School of Orléans and with the School for business management of the Orleans University.

This course is opened to PhD students and can be followed in 3 years so that these students could develop their project in link with their PhD subject and create their enterprise at the end both of PhD studies and entrepreneurship curriculum.

Polytech students are also given the possibility to follow the courses of Master of Institute for Management of Companies of the University of Orléans together with their engineering curricula, this brings them the possibility to learn more about companies and obtain specific skills useful for a manager.

3.2 Partnerships of Polytech Orléans

The partnerships of an institution develop the vision of students and of teachers and make them imagine new innovative subjects.

With School of Design and Art in Orléans especially, the partnership allows students to make their projects with designers, which really opens their mind, it is then possible to follow –one engineering student plus one design student- the course previously described with a real openness and more innovative ideas.

The fact that the school has partnerships with Technological Resources Centers is also a strong factor: for Polytech those centers are in mechanical and electrical domain, they are both located inside Polytech. These two centers are members of national industrial clusters, they are used to answer to industrial solicitations and so, are a good interface between the need of innovation of companies and the potential skills of students. A member of one of these centers is also teacher in Polytech, and the researchers of Polytech are used to work with these centers and their staffs.

3.3 Actions Developed for All PhD Students in HEIs as in Polytech

In France, students graduated from PhD suffer from a lack of recognition from the companies. It is a pity because the PhD graduates could develop innovation. The conference of French Deans of Engineering Institutions (CDEFI) has just launched the course "Skills for Companies" (100 h) that can be followed by PhD students and will help doctors to be able to transfer skills into innovations, this course is also proposed in Polytech, as in some European Universities. It will contribute to the awareness of doctors to entrepreneurship.

4 Action Plan to Support and Develop Innovation in Polytech

The real wish of the direction of a school to develop local entrepreneurship innovation must be measured with an indicator: the number of companies created in the Région Centre (the location of Polytech Orléans) by the engineers graduated from Polytech Orléans.

An action plan has also been decided:

- Create a pre-incubator for companies inside the school: this means a real effort from the direction to put at disposal rooms, logistic, technical devices, and human resource.
- Motivate engineers to the development of innovation, valuing engineer as progress vector: for such it is absolutely necessary to raise awareness of teachers to innovation.
- Value innovative ideas in teaching or research as well for students as for teachers.
- Encourage actions of companies created by students (junior companies), imply teachers to help those initiatives according to the needs and demands.
- Develop innovation among PhD students in Polytech by developing PhD student's counsellors, and create a real network of those PhD students so that they do not feel isolated.
- Employ students to verify the feasibility of dormant projects in small companies (missions in companies) and search for partners that could finance these projects.
- Coordinate Polytech's actions with those of the whole territory and university: develop actions with the competitiveness clusters that are well developed in France.
- Create a Startup lounge and a Fablab inside the school.

5 Other Actions Realized in French Engineering Institutions

The French accreditation agency for Engineering Education CTI, concerned by entrepreneurship and innovation has launched a specific questionnaire to 1/3 of the school that had to be accredited this year (other were asked about other themes specific to the new 2016 criteria); some interesting elements appear in the answers, we present them hereafter.

5.1 The Questionnaire

This questionnaire is called "Focus", this means that CTI wants to focus on the specific points linked to innovation and entrepreneurship.

- First part concerns innovation: education to innovation implies a specific pedagogic adaptation, which experimental practices have been put in place by HEIs? How creativity exercises have been included in these activities?

It is necessary to be able to get a feedback on what has been put in place: how has it been realized?

The project activities are very often linked to practical situation in link with companies' partners of the institution, how is this realized and managed?

- The second part concerns entrepreneurship: does the institution manage this field alone or in a more global frame? How the actions being realized have impacted the entrepreneurship mind of the students?

The CTI intends to communicate about best practices developed in the answers of HEIs so as to share them..

5.2 The Answers of the Institutions

It must be noted that the answers are very positive and documented; this shows that institutions feel really concerned and have already put in place actions.

- About Students

In general, information of students is very progressive, in 3 or 4 steps, as we saw it was done in Belgium.

For example, begin by some informal exchange and round tables where students can discuss together and with young people having already created a company. This sequence can be organized several time during the same year. This initial part is very important because it gives ideas and envy to the students.

A short module (24 h) organized just when students arrive in the school, this module is not mandatory; it includes visits and witnesses; during this short session, students play in team, they present the idea they have developed during a pitch. The skills aimed are creativity, team working, and project management. This part allows to initiate students to entrepreneurial skills.

After this level, it is possible to determine which students are going to become student entrepreneurs.

The third level is then the possibility to become "Etudiant Entrepreneur" through the local PEPITE device, the students can develop their own project together with their studies or at the end of them, they are coached and their status allows them exchanges with various partners to maturate their project.

- About resources: human, logistics

The importance of having a specific place to realize co working is stressed by many institutions, for some kinds of projects the Fablab is also an important resource, resources in time of people dedicated to coaching is something important even at the very beginning of the project, the professional network is recognized as something fundamental at each level, the role of teachers is also underlined.

- About partnerships and links to ecosystem

Many institutions send their students in the neighborhood or partners companies for a week to observe and detect which innovation projects could be developed. This actions have two interests: giving real cases for studies of students and helping companies that don't have the human resources to innovate. The interesting projects can then be developed during the final project at the end or studies.

- About changes state of mind

All the students will not become managers of companies, however many skills such as project management, team working, communication are also those of all engineers. Active pedagogies can be a good support as well MOOC as serious game or learning by doing; this remains for the moment the strong point to be developed.

6 Discussion and New Trends

At the end of the CTI studies, we can see an important lack of theory in the action plans concerning education to innovation and entrepreneurship in French HEIs. Many things still appear as DIY!

PEPITE project did not succeed yet to create a shared culture on those matters.

However, research on those fields is conducted in French institutions [10], but it is not yet shared enough between HEIs, perhaps because of the barrier still existing in some institutions between education and research.

Countries such as Switzerland and Belgium have universities driven by research, this make results of research irrigate much more education.

On the contrary many devices and logistic have already be put in place and all these structures works well.

There is also a "fashion "on entrepreneurship among students at this moment.

So we can imagine that if education develops in fields such as Design Thinking [11] or Effectuation [12] associated with practical experiences that are not often quoted to the answers given to CTI, things could improve.

All this show us the necessity to educate more teachers in this field if we want really to go further.

7 Conclusion

Actions already began in Polytech, three of them were launched:

- A specific day has been used to explain and convince the teachers (most of them being at the same time researchers) of the necessity to innovate. Except PEPITE's one, the means put at disposal of the students can also be used by teachers to create companies from their research or another project.
- The Polytech Startup Lounge has been created in January 2015, it is a pre-incubator, situated inside Polytech. It includes both devices and human resources. A start up mentor has been engaged, he is responsible of the actions of the school concerning entrepreneurship, 22 students (on the 1000 belonging to the institution) already became "student-entrepreneur" and the coaches follow 7 projects of creation of start-up.

  This mentor is able to bring theory in the actions developed, it is an important point.

- A Fab Lab has also been created, it is situated very near to the Startup Lounge, allowing the realization of prototypes. Furthermore, a specific building including all the devices has been proposed for the future.

These last two initiatives show a strong commitment of the direction and are easy to use by students, so their motivation is growing.

However, job has still to be done to reach the goal: we can compare our results to those of our neighbors: the preoccupation of innovation occurred in Belgium 10 years before France and is global both for students and teachers, so we can hope for the future.

Not all students want and can become entrepreneurs, so the role of institution can only be to give appetite and taste to this activity.

The actions already undertaken in European institutions, particularly in France are significant, even if they lack a bit of theory all go in the good direction.

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Application of Graph Theory to Analysing Student Success Through Development of Progression Maps

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Abstract. Student progression is influenced by a number of factors including the pre- and co-requisite structures. Simply viewing pass/fail rates of individual courses is not sufficient to understand an academic programmes progression profile. In this study, the emphasis was on identifying the major obstacles to progression towards graduation.

The approach involved generating progression tree structures that revealed the routes by which students pass through the curriculum. Identifying these routes allows for their support to be implemented in practical ways, e.g. by alternative timetabling so that frequently occurring progression routes would experience fewer scheduling clashes.

It was discovered that an large number of progression paths exist even in a structured degree programmes. Further tree analysis was therefore required. The primary approach was to observe the students on the minimum-time-to-graduate route and to determine which events (which courses) caused students to fail out of the minimum time route. The approach was therefore to determine which courses caused the (remaining) minimum time students fail onto longer graduation routes. This result was further distilled to the top five areas obstructing graduation.

The methods were applied to an undergraduate Chemical Engineering programme. The system identified three courses in the second year second semester of the programme, with one course in particular, ENCH2TD, causing 45% of all minimum time students in that semester to fail out onto a route requiring an extra year of study. The method therefore consistently identified major obstacles to progression in an academic programme.

Keywords: Machine learning · Artificial intelligence · Curriculum structure

1 Introduction

Although concerns had been raised in the past that educational research does not inform curriculum development (Tooley and Darby 1998), in more recent times the importance of research into curriculum development has increased significantly with “Research based curricula” being proposed in the form of a framework for the construct (Clements 2007).

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Systems thinking had penetrated the field of curriculum design as early as 1999; Kessels and Plomp (1999) advocated integrated curriculum design procedures that combined systematic and relational approaches.

However, before such a rigorous approach can be adopted, it is first necessary to define what a curriculum is. This is no trivial task; Glatthorn et al. (2001) define as many as eight types of curriculum. These range from the “Written” curriculum, in which the institution species what is to be taught, to the “Taught” curriculum, i.e. that version which is presented by teachers, to the “Learned” curriculum, i.e. what students learn. As mentioned, there are eight classifications, but these three mentioned are most relevant to the developments of the present paper.

The performance of an academic programme is reflected in the progression of students, however, the definition of progression is also somewhat elusive. Salinas (2009) proposed the existence of two approaches to Learning Progressions, namely the Escalated and Landscape approaches. The escalated approach was composed of a series of levels whereas the second approach presented connections in the form of threads between levels.

There have been other significant attempts at defining student progression. Recently, Learning Progressions and Learning Maps (Sato et al. 2012; Jankowski 2014; Cohen 2015) have gained traction. These progressions and maps, however, do not reveal the routes by which students progress through a curriculum, nor do they attempt to quantify the frequency with which a route is undertaken or the time that a route requires for its completion.

All these attempts begin, in the opinion of the author of the present paper, to imply the application of Graph Theory in analysing curriculum structure. In Cohen’s report (2015), there are illustrations that may be taken from any text on graph theory, even though he does not refer to this field or attempt to use the terminology and methods of this field. Graph Theory has been applied with increasing frequency in other areas of education; an application to Intelligent Tutoring Systems was described by Nabiyev et al. (2016).

In present paper, an approach to developing Progression Maps by way of application of Graph Theory is proposed. However, important reservations have been expressed regarding the development of progression maps. Shavelson (2009) pointed out that learning progressions may well be adapted to fit “various procrustacean beds made by various researchers and reformers bringing the light of day to education reform.”

The methods developed in the field of Big Data show some potential in ameliorating this. Big Data represents a paradigms shift in the means of assessing data; for example, a traditional approach involves the transmission of data to a central server which carries the computational load. In Big Data, however, considering that the large amounts of bandwidth required to move data at the scale required, it is the code that the server transmits to the local server, where the processing is done. Another important principle of Big Data is relatively unstructured nature of the data (Jin et al. 2015).

In order to analyse for progression characteristics, the curriculum structure is required as a minimum. The present paper presents an algorithm for deducing curriculum structure directly from large volumes of student records in a Higher Education Institution’s database.

2 Primary Objective: Student Progression Route Identification

In structured degree programmes, failing a course may result in subsequent courses having to be taken out of the intended sequence of the curriculum design; on the other hand, if the sequence is rigorously preserved, failing a course may result in several subsequent courses shifting to a later year than was originally intended by the student. The net result is that a programme's throughput rate becomes diminished. The extent to which either strategy is applied by staff managing progression will depend in part on the pre-requisites and/or co-requisites of each course in the curriculum. It is probable that courses not considered to contain foundation material for subsequent courses can be taken out of sequence, whereas courses that contain pre-requisites or which serve as pre-requisite of subsequent courses may not be.

Complicating this determination are the sets of 'soft' rules and concessions that programme managers apply to maintain high throughput rates. We classify Hard rules as those rules which apply to all students in an academic programme (e.g. all core courses must be passed for the degree to be considered complete) whereas Soft rules are often concessions which involve a criterion that must be evaluated against a particular student's data. For example, if just one course has been failed in each semester of a particular year, a programme manager may allow a student to 'carry' that course and grant access to the full load courses of the subsequent year, regardless of whether the failed courses were prerequisites. Although application of Soft rules are complicated and time-consuming to the programme managers, they can significantly increase the throughout rates of the programmes concerned.

The more complex and numerous these rules become, the more difficult it becomes for human advisors to apply consistently, opening the door to litigation by students.

Therefore, there are significant challenges that arise due to the multiplicity of the routes by which students are passing through academic programmes. If the routes are known, it becomes possible to apply useful interventions that promote graduation rates. For example, if it is known that many students pass through a programme by route (other than the default curriculum design route), then it becomes possible to create alternate timetables for those students to maintain minimum time to graduation.

Such evaluations are best performed by application of so-called Expert Systems. Expert systems are constituted of software resulting from databases of expert knowledge and typically simply involve the codified version of the hard and soft rules of a system. The Autoscholar Advisor, software that was used in the present study, is an example of a system that applies the principles of Expert Systems together with Machine Learning to develop the rules in an automated way.

Before such analyses can be performed, the progression routes must be determined, and this is the primary focus of the present paper. To develop progression routes, it is first necessary to define Progression and Progression Maps.

3 Research Methodology

3.1 Student Progression Mapping

Student progression is normally defined at a high level, macroscopic way in terms of the numbers of students successfully reaching the stage of graduation. Noel-Levitz (2008) define student progression as "the rate at which a cohort participates in any activity that an institution has determined to be correlated with persistence. Common measures are course completion rates, success rates of students on academic probation, and/or comparisons of academic credit hours attempt vs academic credit hours earned."

Although this definition appears at first glance to be reasonable and useful, in reality there isn't a single rate that can be identified. An average rate exists and can be identified, but, as will be demonstrated in this paper, involves such a high degree of variance as to be meaningless for the sake of drawing conclusions.

In this article, we define progression rate to be the number of credits of the academic programme passed divided by the number of semesters taken to pass those credits. The overall progression rate exists (total credits in a programme divided by total semesters taken by a student to graduate) as well as the local rate (total credits passed in a semester divided by 1 semester) as well as the cohort average progression rate (total credits passed by a cohort after a certain number of semesters have passed).

In reality, a cohort may progress through an academic programme by a variety of routes, each of which will involve its own cognitive coherence. The multiplicity of routes can be classified according to the degree of frequency, and it may be the case that the implementation of an academic programme may or may not cater for the existence of frequently occurring alternate progression routes.

To explore these alternate possibilities, some concepts will be borrowed from the field of Graph Theory. A graph consists of a set of vertices V which may be connected by a set of edges E. A tree is a hierarchical directed graph that will contain no cycles. A vertex on a tree may branch outward into subsequent child vertices.

We may therefore represent the Progression Route of a particular student as a set of nodes connected in series by edges. Each node represents the activities undertaken by a student in a session, that is, in a particular semester of a particular year. The presence of an edge indicates that the student continued the study in the programme that was registered for. Any semesters undertaken while not registered for the programme for which the graph is being constructed is not to be included in this graph (progression route).

We construct a Progression Tree from the superposition of these routes. The degree of scatter, or the variance, of this tree indicates the degree of departure from the original design of that academic programme.

It is further noted that a node is a multi-state representation, since within any given semester, the student will pass a particular set of courses which may or may not be the same as the courses passed by another other student in that same semester. We therefore do not superpose two nodes that differ in the courses passed in that semester. However, for each node that can be superposed for any session i, we anticipate that there exists a frequency f that may reveal the number of students having passed those courses. We may also record the percentage of credits passed p at each node simply by counting the credits passed for each node along the route up to and including the node of interest, and then dividing by the total number of credits required to graduate from that programme.

We may therefore overlay the Progression Tree on a set of axes with the frequency of nodes overlaid against the percentage of credits passed. We call result of this exercise a Progression Map, with a typical example sketched in Fig. 1. In this figure, we anticipate the appearance of such a map for an arbitrary academic programme of 5 semesters (chosen for convenience to allow for the percentage credits passed of the minimum time group to be expressed in 20% increments).

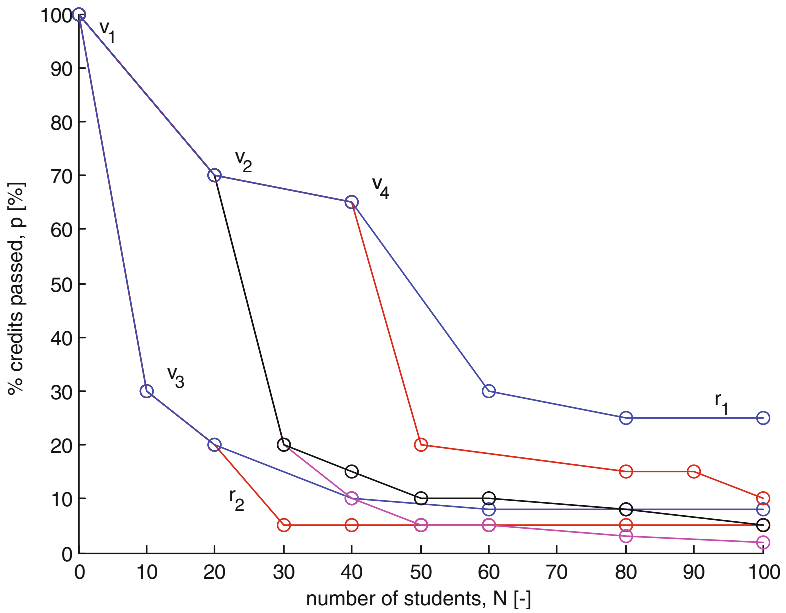


Fig. 1. Anticipated appearance of Progression Map

The figure is shown for an assumed entry by 100 students, none of whom have already passed courses. The node at v_1 is therefore at position (p, f) = (0%, 100). Of this group of 100 students, 70 go on to pass all courses and hence 20% of the credits, whereas 30 of this group only pass 10% (i.e. fail half the courses of the first semester). We therefore have two branches emerging from v_1 as sub-branches emerging at v_2 and v_3. At the end of the second semester, 65 out of the original 70 have passed all courses at v_4, and from this group, only 30 students go on pass all courses in the semester after that.

Therefore, by analysing such a map, it becomes possible to identify specific points in the curriculum where the greatest obstacles to student progression lie. This can reveal a richer set of data than by observing the passrate alone; a progression map helps indicate not only the degree to which students fail a course, but also the progression trajectory that such students then enter as well, together with the indication of how often such a trajectory occurs.

This is an important aspect required for planning; if it is known that a high frequency of students enter a particular route, it is possible to take practical steps such as changing the timetable etc. to facilitate reducing the time to reach graduation.

For the purpose of the present paper, however, it is used to determine the structure of the curriculum itself.

3.2 Algorithm for Progression Map Generation

In developing a clear set of rules that can be used to deduce the curriculum, some processing of the data has to be performed to be able to carry out the operations required. First, the Progression Map must be obtained. According to our definitions here, the map only reveals courses that have been passed, so all course fail student records must be filtered out of the set being used in the construction. This is a relatively easy step in any database query.

We define the Programme Session i as a natural number revealing the time period in which a group of courses may be taken simultaneously. We may further define Δy as the Programme Year, namely, the number of years of study in an academic programme. If y is the current year in real time, and y_0 is the first year of study, also in real time, then $\Delta y = y - y_0 + 1$.

We may also define s to be a natural number which indexes the semesters in any year, i.e. the first semester is at $s = 1$, second at $s = 2$ and so on. This Programme Session may therefore be determined as shown in Eq. 1.

$$i = N_s(y - y_0) + s \tag{1}$$

It is worth noting that a set of i values does not have to be a continuous, so long as i uniquely identifies a session of courses. However, it is preferable for this to be the case so that the value is descriptive. For example, it is easier to understand that $i = 6$ refers to be the second semester of the third year of study.

We now define a Progression Route of student j as r_j which is a graph of vertices $r_{i,j}$, which i is the programme session defined above. In the field of Graph Theory, it is not common practice for the existence of a second subscript to denote a reference to a vertex while its absence denotes the graph itself. However, in the context of Progression Mapping, it turns out to be a convention whose usefulness outweighs the benefits of tradition.

In each session of a progression route, a student will have passed a given set of courses. We accept furthermore that an institution will ascribe a unique identification code to each course (commonly referred to as a course code). Due to their uniqueness, we may use these course codes to define the label of the node $r_{i,j}$ as the string obtained by concatenating all course codes of courses passed in session i by student j. To ensure that all combinations of the same courses are given the same vertex label, it is necessary to sort the course codes in a session in some way (e.g. alphabetically) before the concatenation. It is also useful to apply a delimiter in the concatenation to allow for the decomposition back to the constituent course codes. We define $l_{i,j}$ to be the vertex label at the i^{th}-vertex of route r_j.

We now define a Progression Tree T_j as a graph resulting from the addition of the Progression Routes by all students number from 1 and up to and including j. (Note that, for the purpose of Progression Mapping, we are assigning some consecutive number j counting from 1 upwards to each student.) In the case of the tree, the object at $T_{i,j}$ is not a vertex since at session i, there will generally exist multiple vertices. To distinguish among them, we observe that in the tree T_j, there will exist multiple branches, and if we consider any branch of the tree k, then there will exist vertex $T_{i,j,k}$ of the k^{th} branch in the tree; let $t_{i,j,k}$ be the label of the vertex at $T_{i,j,k}$. So much for definitions.

We obtain the tree T_j by the addition of all routes up to and including r_j, that is

$$T_j = T_{j-1} + r_j = T_{j-2} + r_{j-1} + r_j = \ldots = \sum_{j'=1}^{j} r_{j'}, \text{ where } T_0 = 0 \text{ (an empty graph)}$$

where the sum of a graph and a route is defined as follows. Let us consider the addition of route r_j to graph T_{j-1}. The addition process requires that we loop through each vertex of the route r_j in sequence $i = 1, 2, \ldots, N$. For $i = 1$, we search through all $T_{i=1,j-1,k}$ to obtain $t_{i=1,j-1,k*} = l_{i=1,j}$. We define $k*$ to be the branch on which this label is found, and define this to be our Search Path. If no such branch exists, then create it by adding a new vertex (as a root) to T_{j-1} at $i = 1$ and we define our Search Path to include this vertex.

When adding the i^{th} vertex of r_j, we consider all branches appearing at $T_{i-1,j-1,k*}$. If there is no branch where $l_{i,j} = t_{i,j-1,k*}$ then add a new vertex (as a new branch/child vertex) at session i on branch k. This defines tree T_j. On the other hand, if such a branch does exist, then simply $T_j = T_{j-1}$.

If we perform this addition for all j, we will obtain a tree revealing all possible routes of Progression as a Progression Tree. This is a graph, but it is still not a Progression Map. We define here a Progression Map as a Progression Tree plotted on a set of axes where the x-axis is the percentage of the total credits of the curriculum that have been passed is plotted, and where the y-axis is the number of students who have accomplished this percentage. The co-incidence of a vertex session i at percentage p and at frequency f indicates that there are f students who passed p percentage of total programme credits by their i-th session of study. A Progression Map therefore reveals not only the existence of various progression routes, but the amount of time taken to graduate from the programme via that route as well the number of students who do so in that way.

To construct the Progression Map, we can develop an algorithm by modification of the algorithm used to construct the Progression Tree. We define $f_{i,j,k}$ and $p_{i,j,k}$ to be the number of students and the percentage of credits passed respectively in the j^{th} iteration for session i along route k. In the algorithm at the step of testing for equality of labels, if a label is not found (and hence a new vertex is created), we set $f = 1$ for that new vertex and calculate p according to the total of credits up to that point. If a label is found, we simply increment f and note that there is no need to calculate p since it was already calculated when that vertex was first created.

Once all routes are added we construct the map by drawing the graph and positioning each vertex on a set of axes such that (x, y) = ($p_{i,j,k}$, $f_{i,j,k}$).

This process is summarised in the algorithmic flowchart in Fig. 2.

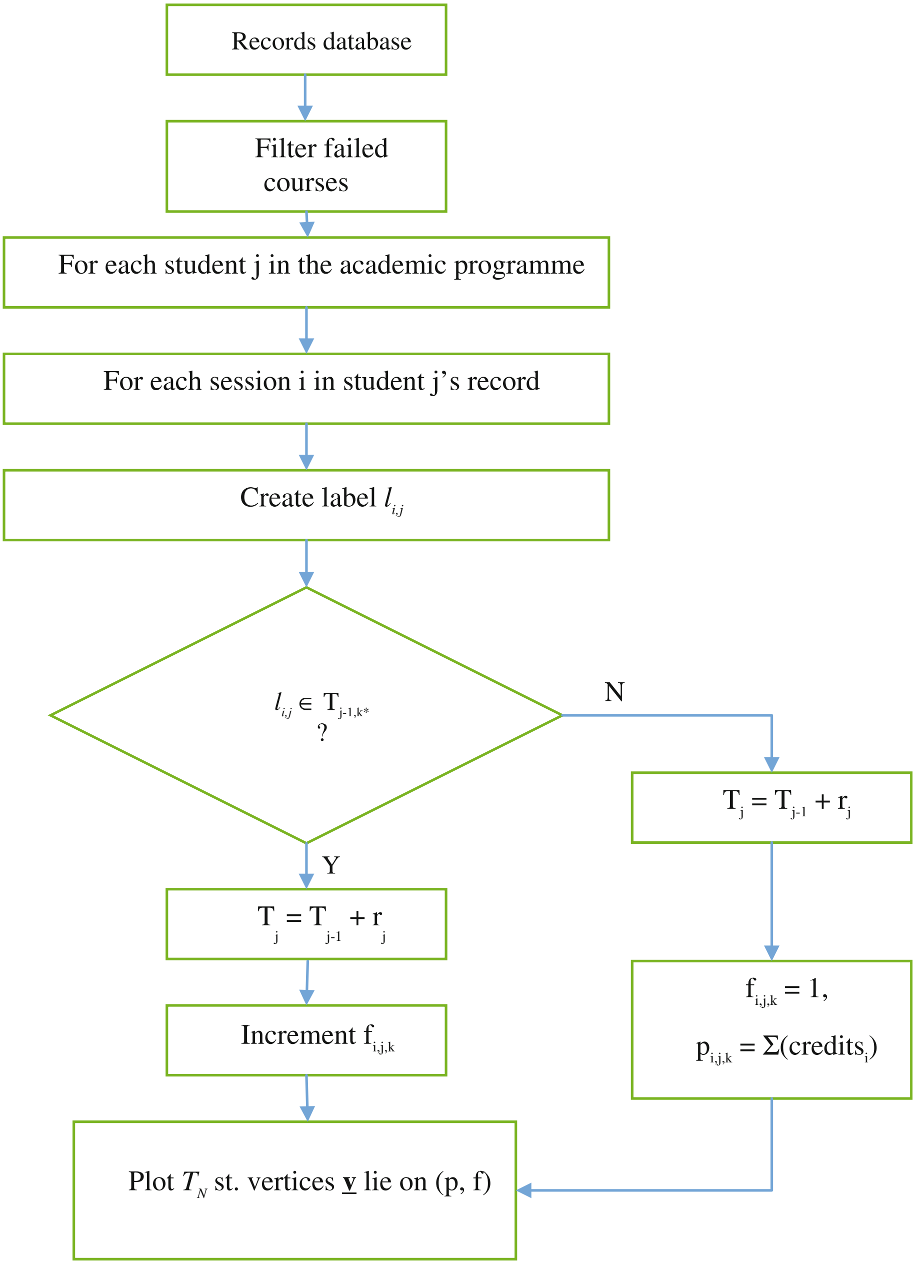


Fig. 2. Progression Map generation algorithmic flowchart

4 Results: Chemical Engineering Case Study

The Progression Mapping algorithm was implemented in the Autoscholar Advisor system and sufficiently generalised to be applied in academic programmes in the College of Agriculture, Engineering and Science at the University of KwaZulu-Natal. Figure 3 below shows the Autoscholar academic programme selector, where a user selects the School or Faculty, and hence the academic programme of interest.

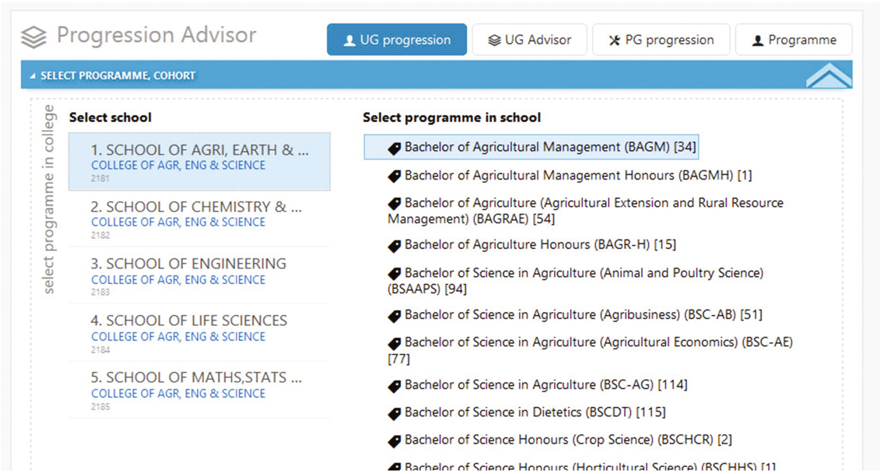


Fig. 3. Autoscholar academic programme selector

The Chemical Engineering programme in the School of Engineering was selected for analysis. The Progression Mapping algorithm developed in the previous section was applied with the result shown in Fig. 4.

The result is significantly more complex than the sketch presented in Fig. 1. When reviewing the data used to generate the graph, it is clear that if a permutation of courses is possible, then some or other student will adopt that route in his or her progression.

The large spikes in the figure are high frequencies in specific semesters; these spikes correspond to the minimum time student cohort, which are in the majority in the first five semesters of the programme. By the second semester of the third year, however, the minimum time group is no longer in the majority. It is therefore not possible to predict the curriculum structure from frequency alone (approach 1, described in the earlier section Principles of Curriculum Deduction).

The total credits required for this programme is 572 (which translates to a total of 5720 notional hours). A slightly longer tail than 572 is observed, due to some students taking additional elective courses.

We also observe that the map does not have as its 'left-most' point the (0%, 100) values anticipated in the original conception; this is due to the students entering the programme by transfer from other programmes at the institution. As such, some students entered carrying credits that were relevant to (hence counted in) the chemical engineering programme.

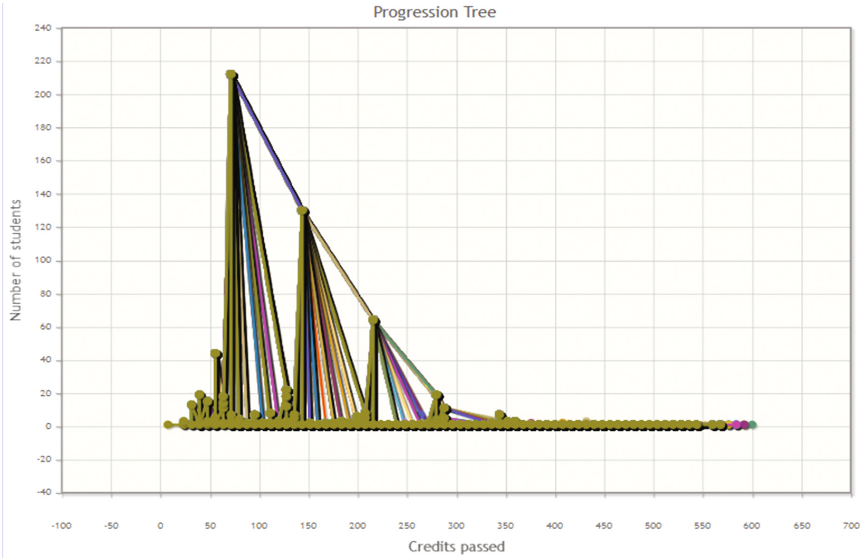


Fig. 4. Progression Map of chemical engineering programme

The applicability of such a graph at this level of complexity to managing progression is limited. However, additional processing of this graph, it is possible to sort the "children" of any given node according to the number of credits passed in the semester. If the associated courses are then accepted as the courses undertaken by minimum-time students, then the algorithm becomes capable of determining the trajectory of the minimum time students.

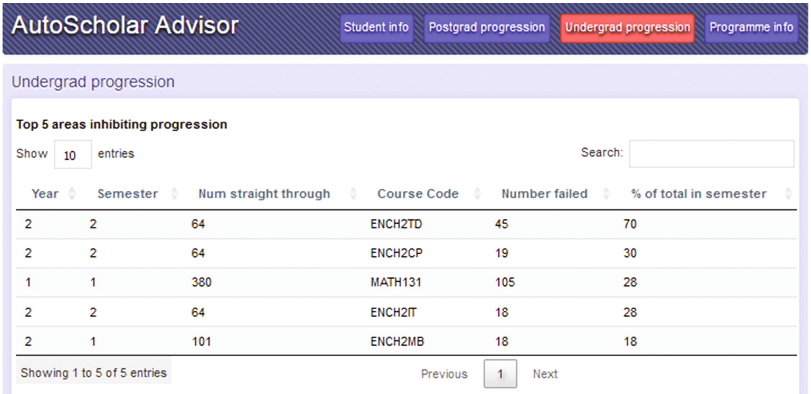
Once a minimum-time trajectory or branch is identified, it is possible to determine which courses in particular are causing formerly minimum students to enter extended time trajectories.

Figure 5 illustrates the results of such analysis. In generating this table, the maximum-credit group was adopted as the minimum time course combination. All departures from this minimum time are then identified as course frequencies.

Progression obstruction summary
Year: 1; Semester: 1; Courses: CHEM161,ENCH1EA,ENCH1TC,MATH131,MATH132,PHYS161 Total: 380
Passed all: 212; % = 56
MATH131: 105; % = 28
ENCH1EA: 61; % = 16
MATH132: 51; % = 13
PHYS161: 25; % = 7
ENCH1TC: 19; % = 5
CHEM161: 12; % = 3
Year: 1; Semester: 2; Courses: CHEM171,ENCH1EB,MATH141,MATH142,PHYS162 Total: 212
Passed all: 130; % = 61
MATH142: 35; % = 17
PHYS162: 34; % = 16
MATH141: 30; % = 14
ENCH1EB: 18; % = 8
CHEM171: 2; % = 1
Year: 2; Semester: 1; Courses: CHEM241,ENCH2MB,ENCH2OM,ENEL2CM,ENEL2EE,ENME1DR,MATH238 Total: 101
Passed all: 64; % = 63
ENCH2MB: 18; % = 18
ENCH2OM: 12; % = 12
ENEL2CM: 11; % = 11
ENEL2EE: 9; % = 9
CHEM241: 7; % = 7
MATH238: 3; % = 3
ENME1DR: 0; % = 0
Year: 2; Semester: 2; Courses: CHEM251,ENCH2CP,ENCH2EF,ENCH2IT,ENCH2MS,ENCH2TD,ENCH2WS,MATH248 Total: 64
ENCH2TD: 45; % = 70
ENCH2CP: 19; % = 30
ENCH2WS: 19; % = 30
ENCH2IT: 18; % = 28
ENCH2EF: 15; % = 23
Passed all: 11; % = 17
MATH248: 7; % = 11
ENCH2MS: 4; % = 6
CHEM251: 1; % = 2
Year: 3; Semester: 1; Courses: CHEM261,ENCH3FD,ENCH3FM,ENCH3HE,ENCH3SL,ENCH3TH,MATH354,STAT370 Total: 11
ENCH3FD: 8; % = 73
ENCH3TH: 5; % = 45
Passed all: 2; % = 18
ENCH3HE: 1; % = 9
MATH354: 1; % = 9
ENCH3SL: 0; % = 0
ENCH3FM: 0; % = 0
CHEM261: 0; % = 0
STAT370: 0; % = 0

Fig. 5. Minimum time losses in terms of the course frequency

By ranking courses according to frequency, the primary causes of progression obstruction by loss of minimum time students to extending progression routes becomes exposed. Figure 6 illustrates the final summary that results from such analysis in absolute and relative terms.



Year	Semester	Num straight through	Course Code	Number failed	% of total in semester
2	2	64	ENCH2TD	45	70
2	2	64	ENCH2CP	19	30
1	1	380	MATH131	105	28
2	2	64	ENCH2IT	18	28
2	1	101	ENCH2MB	18	18

Showing 1 to 5 of 5 entries Previous 1 Next

Fig. 6. Major obstructions to student progression

It is therefore possible to identify with transpacency and rigour the major "gate-keeper" courses in an academic programme even without knowledge of the inner workings of that programme.

Some care is needed in acting on this information; in particular, the reasons for a course serving as a gatekeeper may have little to do with the course itself, e.g. it may be the case that a course is perceived as difficult due to a reliance on earlier courses to establish foundational material; some curriculum revision may be required in this case. The identification of such courses is therefore only a first step in a broader study that must be undertaken in academic programmes exhibiting slow overall progression or high rates of dropout and exclusion.

5 Conclusion

In this article, an algorithm is proposed to deduce curriculum structure by data-mining the student records information. The algorithm is based on the development of a Progression Map, which reveals the routes by which students progress through a curriculum. The map was developed through application of the Autoscholar Advisor system to a chemical engineering curriculum, where it was observed that a large variance of progression routes existed among students. The minimum-time group dropped off fairly quickly; however, since the deduction algorithm is based on the sorting routes according to the number of credits passed rather than frequency of routes, a relatively high prediction accuracy of 92% was obtained. It was also found that the deduction process itself revealed critical information about the programme, specifically, the existence of a gate-keeper course.

The algorithm is therefore best suited to structured degree programmes in which there do not exhibit courses with extremes of low passrates (on the order of 10%). It was also demonstrated that the deduced curriculum could then be used to estimate the excess time taken by individual students to complete the degree, and hence dispense auto-generated advice in terms of the loss of subsidy to the institution as well as the potential earnings losses by students.

It may be possible to extend the range of application of the algorithm by incorporating the influence of elective courses as well as the choices of course options introduced by the existence of majors. Such extensions are planned in the next phases of development of the Autoscholar Advisor. The positive results of the present study illustrates just some of the applications that can be realised in other degrees.

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http://modernscholarship.org.

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A Quantitative Study of the Role of Active Learning and Engagement in Improving Environmental Engineering Students' Learning Performance

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Abstract. The objective of this study was to identify and quantify the key mechanisms through which active learning can enhance the students' level of engagements as well as their learning performance, in the context of environmental engineering. Despite the limitations of the small sample size, positive relationships were observed between active learning, engagement and learning performance. The results provide empirical support for our conceptual framework as student perceptions reveal that the use of active learning techniques promote a greater degree of interaction leading to a better learning experience overall.

Keywords: Active learning · Evaluation methodologies · Improving classroom teaching · Intelligent tutoring systems · Interactive learning environments · Learning communities · Teaching/learning strategies

1 Introduction

A primary reason for the attrition of students from engineering is their perception of a learning environment that fails to motivate them and is unwelcoming [1, 2]. There is an obvious connection between motivation and engagement. It is therefore important to keep the students attention high by keeping the learning experience fresh. This can be achieved by creating an active learning environment, revolving around the use of information and communications technology (ICT), e.g., with classroom response systems (clickers), computer-based tutorials, scaffolded mini-projects [3]. However, there is a lack of quantitative studies that relate the impact of students' perception of active learning to engagement and students' learning performance [4, 7]. Furthermore, there is a need to obtain more data in an Asian context and for environmental engineering students, so as to cover a broad range of educational context and disciplines.

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2 Objectives

Addressing the gaps described above, the objective of this study was to identify and quantify the key mechanisms through which students' perception of active learning can enhance their perception of students' level of engagement and learning performance, through the elaboration of a conceptual framework (Fig. 1).

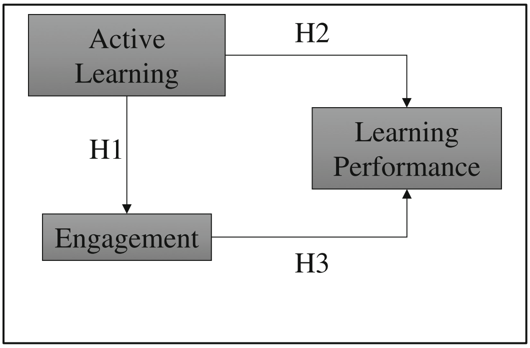

Fig. 1. Conceptual framework

We hypothesize that:

(H1) Students' perception of active learning improves their perception of engagement
(H2) Students' perception of active learning improves their perception of learning performance
(H3) Students' perception of engagement improves their perception of learning performance.

3 Theoretical Framework

3.1 Active Learning

The conceptualization of active learning has been explored in-depth in pedagogical literature. The active learning variable can be defined as the process of students' engagement in activities such as reading, writing and classroom discussions. Such activities usually require problem-solving skills and hence inculcate the ability to analyze, synthesize and evaluate the topic being taught. The term was first coined by English scholar R. W Revans (1907–2003). However, over time, the term has been conceptualized in different ways. According to Bonwell *et al.* [8] "in active learning, students participate in the process and students participate when they are doing something besides passively listening." Weltman [9] stated that Active learning is "a method of learning in which students are actively or experientially involved in the learning process and where there are different levels of active learning, depending on student involvement". Pratton and Hales [10] defined Active Learning as "the result of a deliberate and conscious attempt on the part of a teacher to cause students to participate overtly in a lesson". A number of studies have introduced an interactive element in active learning, called collaborative learning. This would involve students working together in groups on the same topic and towards a common goal. This activity in turn triggers critical and active thinking as students are encouraged to delve deeper into the subject. Further, delving deeper into the subject allows the students to make new associations with the concepts taught in earlier classes (Draper *et al.* [11], Kennedy and Cuts [12]).

There is an ongoing debate whether traditional teaching methods hinder interactions among students. Cotner *et al.* [13]. A certain degree of interaction is required in the classroom among students and with the teacher. In this respect the use of clickers has been useful in promoting such interactions. It leads to an improvement in the students' learning experience and thus a better learning performance (Elliot, [14]; Kennedy *et al.*, [15]).

The relationship between active learning and students' academic performance has been probed as well. Stowell and Nelson [16] found this effect to be enhanced in the presence of technology. Similarly Kryder [17] suggested that the use of technology in the students' learning journey promoted more active learning and hence a better learning performance. Fowler *et al*. [18] and Kreijns *et al*. [19] suggest that the use of technology stimulates both sensory and visual senses, making the students more active learners. Active Learning techniques give the students the opportunity to cognitively process the questions asked by the teacher and improve their understanding of the topic. This has been corroborated by Caldwell [20] and Ribbens [21]. Guthrie and Wigfield [22] state that the use of such technology changes the class environment, promoting more discussion Guthrie and Carlin [23] and Thalheimer [24] pointed out that the use of clickers gives the students control over their own learning journey, hence making them feel that they are co-creating their own learning experience. The term learning performance on the other hand, refers to the final understanding or outcome of the learning process via active learning and engagement. We would therefore expect that active learning promoting techniques would not only improve engagement but also lead to a better learning performance (Ryan [25], Yourstone *et al.* [26]).

Hence we hypothesize:

H2 *Students' perception of active learning improves their perception of learning performance.*

3.2 Engagement

Engagement as a variable has been conceptualized in the literature in varied ways. Some authors have emphasized on the dimensionality and multifaceted nature of the variable. Fredricks *et al*. [27] explored dimensions like emotion, behavior and intellect, whereas Gallini and Moely [28] looked at social, communal and academic aspects of engagement. While this has added depth and allowed for a more meaningful use of the variable, it has also led to a certain degree of ambiguity and weak conceptualization

(Fredricks *et al*. [29]). Since this study looks at students' perceptions of active learning, engagement and learning performance, engagement has been defined as the student's perception of his/her interaction with others. This includes peer interaction as well as interaction with the teacher during the learning period, leading to greater involvement in the topic being covered.

In this module, an attempt was made to increase student interaction using different learning techniques mainly through information and communication technology (ICT) methods. These included the use of response systems like clickers, online climate models and discussion forums. Such methods are capable of changing the academic environment to foster greater interaction and change students' perception of engagement (Finn and Rock [30]). This was further explored by Guthrie and Wigfield [31], who concluded that engagement acts as a catalyst for bringing about a greater impact of changing academic environment on students' engagement.

This relationship has been explored in-depth in the literature. Mayer *et al.* [32] linked students' learning performance to the way they engage in intellectual thought processes. As a result, Shernoff [33], Baker *et al.* [34], Kuh [35] and Marks [4] thought high interaction and engagement have been important for success, sustaining motivation, commitment and a better learning performance. Engagement is seen as important in classroom settings as it operates as a behavioral path through which students' motivation contributes to a better learning performance. Wellborn [36] states that engagement becomes important for the teacher as well as it serves as an indicator of a student's motivation.

In this module, an important component of the ICT methodology was the use of clickers. Clickers are audience response transmitters. They facilitate quick responses from students, when asked questions in class. The student's responses are then graphically depicted on the screen and students can see the overall response of the class. The clickers have been known to be beneficial active learning devices. Bergtrom [37], Bullock [38] and Simpson and Oliver [39] agree that the use of clickers has a positive effect on students' learning performance.

Overall, the significant benefits identified lead us to expect a positive effect of clickers on student learning performance. A number of studies have looked at the relation between the clickers and improving students' engagement. Blasco-Arcas *et al.* [30] looked at the effect of use of clickers on learning performance. Using a confirmatory factor analysis (CFA) approach, the study concluded that the interaction resulting from the use of clickers affects engagement and active learning and hence learning performance. On the same note, Caldwell [39], Brewer [31], Hu *et al.* [40] and Kenwright [33] believe that the use of clickers had a direct impact on students' academic scores.

Hence considering the above discussion, we hypothesize:

H1 *Students' perception of active learning improves their perception of engagement*
H3 *Students' perception of engagement improves their perception of learning performance.*

4 Methodology

This study examines an undergraduate level module of Environmental Engineering offered by the National University of Singapore. The study was administered over two semesters of the course for two batches of students. The first batch consisted of 66 students and the second batch consisted of 60 students. Three ICT-based active learning activities were implemented throughout the course of the learning period. First, clickers' quizzes were interspersed alongside lecture material; Second, hands-on sessions on online climate models were incorporated into the tutorials and third, students were given a project for which they were assessed based on a video presentation. Towards the end of the course, an anonymous survey was administered to the students comprising 34 items. Finally focus group interviews were conducted to gain a more in-depth understanding of the factors that affected the students learning performance in this module.

4.1 Participants

One hundred and twenty students of the environmental engineering module over two semesters took part in this study. 66 out of the 120 students participated in the anonymous survey, yielding a response rate of 55%. Among the 120 students, sixteen were randomly selected to take part in the focus group interviews.

4.2 Data Sources and Analysis

The original questionnaire consisted of 34 items developed to measure students' perception of active learning, engagement and learning performance. An exploratory factor analysis (EFA) using principal component extraction was done to extract the items loading on each factor. Given the small sample size, the Kaiser-Meyer-Olkin (KMO) and Bartlett's tests of sphericity tests were performed to check the adequacy of the data for factor analysis. The tests confirmed the adequacy of the current data for analysis with KMO values being greater than 0.7. Following factor analysis, the items that did not load highly on any factor or loaded on multiple factors were eliminated. Finally, the Cronbach's Alpha coefficients, which are used to check the internal consistency of the factors, were .83 for Active Learning, .85 for Engagement and .93 for Learning Performance (See Appendix).

In order to calculate the linear relationships between the three factors, a Pearson bi-variate correlational analysis was conducted. Lastly, in order to understand the directional relationships between the three factors, a linear regression analysis was performed.

4.3 Focus Group Interviews

The main purpose of the focus group interviews was to gain a deeper understanding of the issues raised by the students in the anonymous surveys. The questions were open-ended to prompt diverse responses. The interviews lasted for a duration of 15 min each. The entire session was audio recorded and transcribed. The questions asked included:

Were the clickers and the questions raised during the lectures effective in keeping you interested?

Did the feedback and interaction during the mini projects lead to a better understanding of the topic?

If given two alternatives of studying a particular topic, first by means of written assignment/presentation and second by means of the mini project/video recording: which one would you prefer and why?

Did you think that you benefitted from face-to-face sessions/interactions with the professor?

In what way/s do you think the teaching methods in the module could have been improved to lead to a better overall learning experience?

5 Results and Discussion

5.1 Factor Analysis

A 19 item anonymous survey with 3 sub-scales, namely active learning, engagement and learning performance scales, was administered to the students at the end of the course. In order to refine the scale, an exploratory factor analysis using principal component reduction technique was employed. Factors that did not load highly on the factors or cross-loaded on multiple factors were eliminated. Items with factor scores greater than 0.6 were retained in the item scale. Although studies have adhered to different threshold levels to decide on whether the items should be included, 0.6 has been generally accepted [6, 30].

The final questionnaire consisted of 6 items for Active Learning, 8 items for Engagement and 11 items for Learning Performance. A summary of the factor scores and Kaiser-Meyer-Olkin (KMO) and Bartlett's test statistics is shown in the Appendix. KMO scores greater than 0.7 indicate a high level of sample adequacy [5]. All three factors showed KMO scores of greater than .75. The three factors were then extracted as variables and then subjected to further analysis.

5.2 Correlation Analysis

Pearson bi-variate correlation analysis was performed to check for statistical relationships between the three factors. A summary of the relationship is shown in Table 2. The results indicate a positive and significant relationship between active learning and engagement ($r = .82$, $p < 0.01$), showing that students who rated active learning items higher on the Likert scale also tended to agree that the module was engaging. It is possible that the students felt the use of clickers to be more engaging than conventional lecturing techniques. Next, there was a positive and significant relationship between Engagement and Learning Performance ($r = .86$, $p < 0.01$), indicating that students who reported high levels of engagement also felt that it lead to a better learning performance. Lastly, a positive and significant relationship was found between active learning and learning performance (r = .84, $p < 0.01$). This could imply that students who assigned high ratings to active learning tended to have a better learning experience as well (Table 1).

Table 1. Pearson's correlation coefficients

Variables	Active learning	Engagement	Learning performance
Active learning	1	0.818*	0.837*
Engagement	0.818*	1	0.862*
Learning performance	0.837*	0.862*	1

*Correlation is significant at .01 level (2-tailed)

5.3 Regression Analysis

Linear regression models were used to further analyze the relationship between active learning, engagement and learning performance. Three hypotheses were tested by fitting the best-fit model to the factors extracted:

(H1) Students' perception of active learning improves their perception of engagement
(H2) Students' perception of active learning improves their perception of learning performance
(H3) Students' perception of engagement improves their perception of learning performance.

Table 2 summarizes the results of the simple linear regression analysis, including the unstandardized coefficients (B), standard error (SE), t-value, standardized regression co-efficient, significance level, R-squared and adjusted R-squared. The analysis reveals significant relationships between the factors indicating some predictability. Model 1 examined the relationship between active learning and engagement. The regression co-efficient was significant and positive (B = 0.835, t = 11.36). Active learning and engagement usually complement each other as the former involves

Table 2. Summary of Linear Regression Analysis

Model	B	SE	t-value	Sig.*
Model 1 active learning improves engagement $R^2 = .669$ Adjusted $R^2 = .818$	0.835	.074	11.362	.000
Model 2 active learning improves learning performance $R^2 = .837$ Adjusted $R^2 = .700$	0.855	.070	12.235	.000
Model 3 engagement improves learning performance $R^2 = .862$ Adjusted $R^2 = .743$	0.862	.063	13.588	.000

continuous peer and teacher interaction [10]. General consensus in the focus group interviews showed that constant interaction kept the students motivated and hence enhanced engagement in the classroom. Working in groups during the mini-project and video recording, set up a system of discussion and continuous feedback. This kept the students further motivated to produce a better final product.

Model 2 explains the relationship between active learning and learning performance. The regression co-efficient is positive and significant at .01 indicating that active learning techniques lead to an improvement in learning performance (B = 0.885, t = 12.23). It is possible that constant feedback from the lecturer and among peers allowed for a more in-depth discussion and hence a better understanding of the topics taught. The course design included a more practical approach through the use of online climate models and video recording of the mini-projects. Departing from the traditional methods of lecturing, these methods hence show a significant impact on students' perception of their learning performance.

Finally model 3 looks at engagement as the independent variable and learning performance as the dependent variable. The regression co-efficient (B = 0.862, t = 13.588) is positive and significant indicating that engagement indeed impacts the learning performance of students. An important point raised in the anonymous survey as well as the focus group interviews was how the diverse methods used were unique and different from the conventional teaching techniques. Students generally agreed that the use of clickers during lectures and video recording of mini projects kept them engaged and interested in the topic taught. As discussed in the conceptualization, better active learning techniques letter to greater engagement and motivation, which in turn led to a better learning experience.

5.4 Focus Group Interviews

The focus group interviews were transcribed and analyzed to pick out and identify important themes. The participants were asked open-ended questions about their perceptions of the teaching methods used in the module. Given the factors, active learning, engagement and learning performance, the important themes identified were (a) medium of instruction, (b) peer interactions and (c) practical applications

5.4.1 Medium of Instruction

The majority of the students interviewed mentioned that the alternative methods used in the module led to a better understanding of the topics taught. Several agreed that the use of clickers created a lively and interactive atmosphere in the classroom. The students were asked questions after a particular topic was completed, leading to a recap and in-depth discussion of the content learned. The answers received were graphically depicted and discussed in the classroom, which gave the students a better picture of the question asked. Most students felt that the clicker questions were very timely and a revision of concepts taught earlier. The fact that the students were allowed to discuss the answers with their classmates intensified the learning experience by introducing an interactive element.

One participant mentioned:

I think the clickers were quite good in terms of catching our attention and not making us sleepy. After the answer was revealed, we were asked what our choice was. The atmosphere was hence quite fun and lively.

However not everyone agreed on the effectiveness on the use of clickers. Some were unclear on the purpose of using the clickers during the lectures, and hence could not agree if the use of the clickers was indeed meaningful. A student pointed out that since there were no grades assigned to actually using the clickers, it was difficult to stay motivated in class. For example a participant said:

I think some of us were thinking if it was an attendance ticker. We were thinking about the reason why the professor was using it and were not really sure of the purpose.

Further, in the focus group interviews, the participants were asked, if given a choice between the conventional way of doing the project via PowerPoint presentations and video recording of the mini projects, which one they would prefer. Most agreed that the video recording was unique and allowed them to put their creative skills to the test. However a few were of the opinion that the video recording consumed a lot of time and effort. An anonymous participant mentioned:

We took a lot of time to make the video and it took a lot of effort, but the weightage was very less. Especially if the video submission clashed with the lab reports, it was hectic.

5.4.2 Peer Interactions

An important consequence of the active learning approach adopted was the continuous peer and teacher interaction involved. Students were made to work in groups of twos or threes for their mini projects and also encouraged to participate by asking as well as answering questions in the online discussion forum. Additionally, they also benefitted from one-on-one interactions with the teacher. When asked about the effectiveness of working in groups, many were of the opinion that it led to a more efficient use of time. They felt that the varied opinions helped and different approaches to the same problem led to a better final product. This was evident from one particular participant's response:

If we did individual work, it would not have been productive, since we had video presentations, it would have been difficult if only one person did all the work. It would have been less enjoyable.

Another participant said:

I worked with three people and I think group work is always more enjoyable than individual work. It lightens your workload, and is lot more efficient. The project involved lot of research, which was time consuming. We managed to do the actual production in one day, which would have been impossible to do alone.

5.4.3 Practical Application

The main aim of introducing this unique and unconventional teaching approach was to keep engineering students motivated to study the field. Conventional textbook learning often fails to provide real life examples and practical applications. As part of the ICT teaching method, the students were given a hands-on-session on online climate models.

While most agreed that the use of the models was interactive and useful, others found the models difficult to comprehend and were unable to link them to the topics being taught. This was evident from one participants view:

The last few sessions we did the online models. I didn't really understand what we were doing with the models. We didn't understand the link between what we were doing and the tutorials, and how the graphs change with the numbers. But we tried.

Some were of the view that the model could have been simplified. This would have helped them in understanding it better:

The main benefit of having the models online was to be able to play with them and see the model prediction. The problem was that if there was any purpose for us to be able to compare between models or even basically understand what is the difference between them it was not achieved.

I didn't really get the model as it was just about following the instructions and writing the answer given

However few were of the view that the models were easy to use and assisted in understanding the chapter better.

It isn't something commonly seen for students, and broadens my perspective on the different impacts and consequences of our actions.

The online climate models helped me to understand the effects of global warming on the Earth better, by showing me simulations and estimations of future scenarios.

It helps us to understand what is contributing to climate change and thus what are the mitigation steps we need to have.

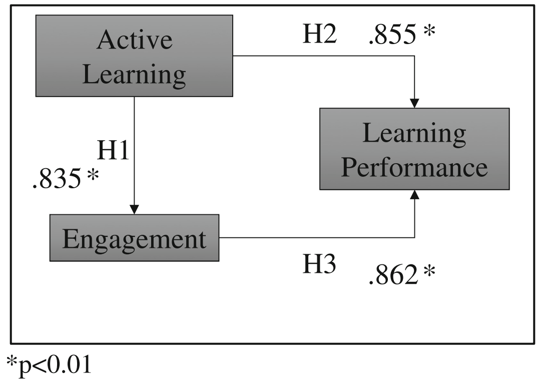

Fig. 2. Relationships among active learning, engagement and learning performance *p < 0.01

6 Conclusions

The main objective of this study was to identify and quantify the key mechanisms through which active learning could enhance the students' level of engagement as well as their learning performance. The first step in the analysis was to subject the 34-item survey to an exploratory factor analysis using principal component extraction.

Following this, the items that did not load on any factors were eliminated and the instrument was refined. The next step was to look at the relationship between the extracted factors. For this, the Pearson's bi-variate correlation test and simple linear regression models were employed. It was found that participants who had high-perceived levels of active learning, also thought that the methods used were engaging. Students, who perceived high levels of engagement, also had a better learning performance in the module. While the correlation analysis revealed information about co-movement among the factors, the linear regression analysis examined the direction of this movement. Figure 2 summarizes the regression results.

The first relationship was that active learning led to an improvement of students' learning performance. The participants were students of an undergraduate environmental engineering module, which was specially designed using ICT methods. The use of clickers was one method that was used to promote active learning. Students were given individual clickers to answer questions asked during the class. The teacher then followed-up with a discussion of the answers and revision of the topics taught. Additionally, a number of students during the focus group interviews mentioned that the use of clickers make the class more lively and allowed them to think on the spot. The next relationship examined was between learning performance and engagement; regression coefficients pointed out that higher levels of engagement also lead to an improved learning performance. This relationship between engagement and learning performance is supported by qualitative data as well. A number of participants agreed that working in groups for the mini projects and interactions with the lecturer via tutorials was effective in producing a better learning outcome. The constant interaction and feedback from their peers helped in producing a more efficient and high quality final product. This has been corroborated by a number of scholars, who suggest that engagement and collaboration plays an important role in learning performance [26–29].

Finally this study looked at the relationship between active learning and engagement. The main goal of the study was to keep the students engaged and motivated through active learning methods. The use of clickers and the online discussion forums prompted a more interactive environment. As opposed to conventional lecturing, participants in the focus group interviews found the use of ICT methods to be more engaging. This can be seen from the positive and significant regression coefficients as well.

In conclusion, the present study showed that students' perception of learning performance, active learning and engagement were strongly inter-related. Several researchers have studied the effect of increased engagement and active learning; however the impact on learning performance has not been analyzed with respect to a small sample size. This study therefore has significance for lecturers who teach small classes and often cannot assess the efficacy of their teaching methods, as they do not have access to large sample sizes. While qualitative research methods, such as focus group interviews, have the merit of providing a deeper understanding of students' perceptions, a quantitative approach detects and brings out patterns. The correlation and linear regression analysis quantifies the impact of the active learning techniques on students' engagement and learning performance, thus corroborating the results of the qualitative analysis. Although the use of such techniques may promote student learning, it may also negatively affect their performance, as was evident from some views that emerged during the focus group interviews. Hence it is imperative for educators and course administrators to design a module or course in a manner that makes the overall learning experience more meaningful and satisfactory.

Appendix A. Active Learning, Engagement and Learning Performance Questionnaire

About the lectures

1. I find that the lecture sessions were engaging
2. I find that I was actively engaged during the lectures
3. I find that the clickers were meaningfully used during the lectures
   If yes, how has it been useful?
   If no, please elaborate
4. I find that the clickers allowed me to interact with my classmates
5. I find that the clickers allowed me to interact with the teacher
6. I find that the questions posed during lectures were helpful in allowing me to better understand the concepts

About the tutorials

7. I find that the tutorial sessions were engaging
8. I find that I was actively engaged during the tutorials
9. I find that the tutorials allowed me to interact meaningfully with my classmates
10. I find that the tutorials allowed me to interact meaningfully with the teacher
11. I find that the tutorial problems were helpful in allowing me to better understand the concepts taught during lectures
12. I find that the use of online climate models was meaningful
13. I find that the use of online climate models was helpful in allowing me to better understand the concepts

About the mini-projects

14. I find that the pace at which the mini-projects progressed was adequate
    If no, was it too fast or too slow
15. I find that the video recording of the mini-projects was a meaningful approach
    If yes, how has it been useful?
    If no, please elaborate
16. I find that the video recording of the mini-project gave me the freedom to participate in my own learning experience

17. I find that the video format for the mini-projects was more engaging than a conventional presentation format
18. The interim report and dedicated tutorial sessions were useful in improving my understanding of the mini-project
    If yes, how has it been useful?
    If no, please elaborate
19. I feel that the discussion forums allowed me to interact meaningfully with my classmates
    If yes, how has it been useful?
    If no, please elaborate
20. I feel that the feedback obtained from my classmates via the discussion forum improved my understanding of the mini-project
    If yes, how has it been useful?
    If no, please elaborate
21. I feel that the diverse activities have allowed me to progressively improve my understanding of my mini-project
    If yes, how has it been useful?
    If no, please elaborate
22. Overall, I find that the mini-project have allowed me to co-create my own learning experience
23. Overall, with the mini-projects, I find that my opinions have been taken into account in this course
    If no, please elaborate
24. With the mini-projects, my peer and faculty interactions made me feel valuable
    If yes, what made you feel valuable?
    If no, please elaborate

My general impression of the teaching methods used in this module

25. Overall, I feel that the diverse methods used in this module have allowed me to better understand the concepts
    If yes, how has it been useful?
    If no, please elaborate
26. Overall, the diverse methods used in this module have improved my interest in the topic
    If yes, how has it been useful?
    If no, please elaborate
27. Overall, I felt engaged in this module
28. Overall, I feel that I have actively collaborated in my learning experience in this module

Appendix B. Factor Analysis Results

1. **Factor Analysis: Active Learning**

KMO and Bartlett's test		
Kaiser-Meyer-Olkin measure of sampling adequacy.		.771
Bartlett's test of sphericity	Approx. Chi-Square	275.160
	df	28
	Sig.	.000

	Factor	
	1	2
SPBL24	.796	−.224
SPBL25	.787	−.228
SPBL3	.713	.384
SPBL21	.676	−.540
SPBL4	.661	.390
SPBL9	.656	.373
SPBL10	.525	.292
SPBL22	.502	−.413
Extraction Method: Principal Axis Factoring.		
a. 2 factors extracted. 11 iterations required.		

2. **Factor Analysis: Engagement**

KMO and Bartlett's test		
Kaiser-Meyer-Olkin measure of sampling adequacy		.823
Bartlett's test of sphericity	Approx. Chi-Square	434.350
	df	45
	Sig.	.000

	Factor	
	1	2
SPBL26	.896	.130
SPBL18	.771	
SPBL28	.761	.107
SPBL1	.760	.467
SPBL17	.747	
SPBL7	.735	−.493
SPBL8	.721	−.547
SPBL2	.623	.294
SPBL6	.518	.214
SPBL12	.517	
Extraction Method: Principal Axis Factoring		
a. 2 factors extracted. 9 iterations required.		

3. **Factor Analysis: Learning Performance**

KMO and Bartlett's test		
Kaiser-Meyer-Olkin measure of sampling adequacy.		.849
Bartlett's test of sphericity	Approx. Chi-Square	603.452
	df	105
	Sig.	.000

	Factor		
	1	2	3
SPBL33	.821		
SPBL29	.788	−.189	.100
SPBL23	.759	.301	
SPBL27	.757	.133	.160
SPBL31	.740	−.203	−.223
SPBL30	.691		.497
SPBL32	.688	−.536	
SPBL13	.686	−.446	
SPBL34	.685		−.107
SPBL16	.673	.320	
SPBL11	.635	−.146	−.195
SPBL14	.573	.449	−.124
SPBL15	.544	.300	−.280
SPBL5	.516	.191	.451
SPBL19	.487		
Extraction Method: Principal Axis Factoring.			
a. 3 factors extracted. 11 iterations required.			

4. **Cronbach's Alpha: Active Learning**

Case processing summary			
		N	%
Cases	Valid	66	35.2
	Excluded[a]	68	64.8
	Total	135	100.0

Reliability statistics	
Cronbach's Alpha	N of items
.831	8

5. **Cronbach's Alpha: Engagement**

Case processing summary			
		N	%
Cases	Valid	66	35.2
	Excluded[a]	68	64.8
	Total	135	100.0

Reliability statistics	
Cronbach's Alpha	N of items
.849	10

6. **Cronbach's Alpha: Learning Performance**

Case processing summary			
		N	%
Cases	Valid	66	35.2
	Excluded[a]	68	64.8
	Total	135	100.0

Reliability statistics	
Cronbach's Alpha	N of items
.930	15

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Breadth Experiential Courses to Flexibly Meet New Programme Outcomes for Engineers

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Abstract. Engineering students must constantly acquire new skills to meet fast evolving graduate profiles. Because they are accessible to non-majors, breadth courses permit to expose students to a wide range of perspectives outside of their regular engineering programme. It has been showed that such courses reinforce students' motivation and self-confidence. They may also strengthen transdisciplinary and transferable skills, while remaining aligned with the profession requirements. Based on this assumption, through a qualitative analysis this chapter presents a navigation and sea risks breadth course, including in-situ real experiences aimed at future engineers in a generalist French outcome-based integrated curriculum. In triggering judgment and decision-making skills, as required since 2016 by the European accreditation body for engineering education, this breadth course permitted students to develop higher confidence in their ability to grasp complex situations, to adapt dynamically to unexpected circumstances, and to act in uncertain and unstable contexts.

Keywords: Engineering education · Breadth courses · Curriculum innovation · Outcomes based education · Judgment and decision-making · Qualitative analysis

1 Introduction

Nowadays, engineers are essential to apply new sciences and to design and implement new technologies in order to create smarter societies. To be able to meet such challenges in a fast changing world, students must constantly acquire new skills so as to meet evolving graduate engineering profiles. This need to persistently adjust our students' scientific and technical attributes is not the only reason for the relentless evolution of engineering education. There are also other shifts which address the same concern. For instance, various subjects pertaining to humanities and social sciences are now part of several accredited engineering programmes, via traditional teaching models or multidisciplinary learning approaches based on problem- or project-based learning (PBL and PjBL). Thanks to this kind of addition, engineering students may take advantage of an innovative engineering training and education to better anticipate

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future required proficiencies and professional capabilities. The expected 4^{th} industrial revolution will reinforce the need for engineering educators to revamp their curricula and to overcome the intrinsic inertia of engineering programmes which hampers their efforts to dynamically address and anticipate societal challenges, especially when they rely on an old paradigm of programme structuration. Moreover, in a context of increasingly unstable and rapidly changing environments, that strategic business leaders are calling VUCA (for the volatility, uncertainty, complexity, and ambiguity of environments), programme designers and engineering educators must continuously innovate both in their curricula and teaching/learning methods, so as align with outcomes assessment strategies.

Reengineering or rearchitecting a programme is a rather long process, and, if not carefully pondered, adding new courses to the formal curricula often generates inconsistencies at a systemic level. Introducing liberal arts subjects into a Bachelor or Master engineering programme architecture permits to include, flexibly, knowledge and skills which are not directly linked to traditional accreditation or professional body requirements. In the USA, liberal arts education is well established in colleges, leading for example to a Bachelor of Science degree or in some cases to a Bachelor of Science in Engineering degree. In Europe, even if the liberal arts style is deeply rooted in some countries, "there is no consensus in structuring engineering education, but rather a constructive diversity in programme design" [1]. In countries such as France, generalist integrated educational architectures do not offer the same level of flexibility to curriculum designers as liberal arts programme architectures. In integrated programmes, several intended learning outcomes, which relate to programme outcomes areas defined by accreditation bodies or professional branches, are to be fixed at design time (cf. outcome-based programme design). Then, these outcomes may be mapped at all levels of the curriculum into learning activities, which are to be integrated into courses. By the end of their studies, engineering students may then validate their competence in the various areas pursuant to constructive alignment. As a European example, in the French engineering education model, generalist curricula are a tradition in the highly selective *Grande Ecole* system [2]. Among these typically French selective higher education institutions, the *Grandes Ecoles d'Ingénieurs* lead to a Master of Engineering degree in three years, preceded by two years of national intensive so called *Preparatory Schools* delivering mainly in-depth knowledge and understanding of mathematics and physics after K12 levels for top students. These engineering *Grandes Ecoles*, which traditionally offer a balance of scientific, technical and non-technical courses, increasingly consider integrated programme models so as to better align with up-to-date graduate attributes and programme outcomes [3], e.g. as fixed by engineering education accreditation bodies or as recommended in syllabus of international educational frameworks (e.g. the EUR_ACE® framework [4], the French *Commission des Titres d'Ingénieur* [5], the Accreditation Board for Engineering and Technology, the CDIO initiative [6]).

In France, with a separation of engineering from other Science programmes, generalist engineering programmes are attractive to students who had previously not considered engineering. In another context, Alpay [7] indicates that a generalist engineering programme is highly attractive to students who are considering an engineering degree, and also to some students who had previously not considered engineering. Nevertheless, strongly coupled and integrated curricula, as in many French engineering institutions, are characteristics which may impact student motivation when the focus is merely in engineering. In a Scottish University context, Christie, Munro, and Fisher [8] showed via comparison groups that factors inducing the student to withdraw include poor choices of course, limited social support networks, and lack of 'fit' between the students and their institution. As regards the first factor, it seems legitimate to consider that the level of course coupling and integration in a curriculum is to affect the student's motivation.

It is critical to reinforce students' self-confidence for engineering careers [9]. Recently, Holmegaard, Madsen, and Ulriksen [10] found that students' expectations about engineering are poorly satisfied by their actual experiences during their first-year study programme. Without neglecting the alignment of programme outcomes with new skills, and with a view to offering students more flexibility in its integrated engineering curriculum and increasing student motivation and self-confidence, IMT Atlantique (formerly Telecom Bretagne, a public accredited French *Grande Ecole*) introduced breadth courses accessible to non-majors in its integrated programme architecture in 2003. To exemplify and analyze its innovative architecture, this chapter first explores the expected benefits of such breadth courses in the next Section and then clarifies breadth courses integration in the so-called "inter-semester weeks". Alignment with programme outcomes is discussed in that flexible context, with a specific focus on transdisciplinary skills such as judgment and decision-making, used as examples in this chapter, as they are in line with the evolution of graduate engineering profiles. Then, the specific one-week course "Navigation and Sea Risks" held in January 2016 is presented and supported by a qualitative analysis to show its benefits in the integrated engineering programme. This chapter concludes with potential future work for the 2017 inter-semester session so as to reinforce student confidence and efficacy, such as decision-making abilities in uncertain complex situations.

2 The Introduction of Breadth Courses in the Intersemester Weeks of IMT Atlantique

As defined by Simon Fraser University[1], to qualify as designated breadth, a course should be "intellectually accessible to non-majors; that is, a student's ability to master the course content should not depend on bringing to it the kind of specialized knowledge typically possessed by students majoring in a discipline. Thus, breadth courses mainly cover outside of the student's major, e.g. breath-Humanities, breath-Social Sciences. A breadth course exposes students to concepts and ideas from a range of disciplines and perspectives outside of their programmes".

[1] SFU Undergraduate Curriculum Initiative: Breadth requirements. Available from https://www.sfu.ca/ugcr/for_students/wqb_requirements/breadth.html (consulted in January 2017).

2.1 Curriculum Integration of Breadth Courses

Aside from multidisciplinary team-based semester projects [3] and classical core courses, IMT Atlantique started integrating breadth subjects in 2003 via so-called inter-semester week courses on the Telecom Bretagne campus. In practice, engineering students (freshmen and sophomores) must select two subjects among a large set of breadth courses. This set evolves each year, depending mainly on the dynamic context, student engagements and faculty motivations. In January 2016, 30 breadth courses were proposed, including *inter alia* Deep Learning; Business Intelligence; Risks in Mountain; Leadership; Art Design; Geopolitical Energy Crisis.

Each breadth course at Telecom Bretagne is optional but credited (2 European credits, aka ECTS) and has a one-week duration. As set out in Table 1, breadth courses (termed INT in the agenda) are positioned in the middle of the year, right after the semester exam sessions. In an academic year, a student must select one major (16 credits, e.g. Math and Signal Processing, Electronics and Physics, Computer Engineering, Networks, Economics and Social Sciences) and one minor (8 credits, more oriented towards basic understanding of systems rather than deep analytical or technological aspects) per semester. In addition, he/she must actively participate in a team project during 14 weeks (6 credits), generally one day per week and per semester [3]. Finally, he/she must achieve a required and certified level in two foreign languages and follow a compulsory career-course (e.g. others).

Table 1. Programme structure at IMT Atlantique, Telecom Bretagne campus (2003–2017 educational programme architecture).

<table>
<tr><th colspan="5">Academic Year_i</th></tr>
<tr><td>Major</td><td>Minor</td><td rowspan="4">INT 1,2</td><td>Major</td><td>Minor</td></tr>
<tr><td colspan="2">Languages</td><td colspan="2">Languages</td></tr>
<tr><td colspan="2">Semester PjBL</td><td colspan="2">Semester PjBL</td></tr>
<tr><td colspan="2">Others</td><td colspan="2">Others</td></tr>
</table>

In 2016, 17 breadth courses were proposed in week 1 (out of the 30) and also 17 in week 2, with a cohort of around 350 students. Among these breadth courses, 11 were new courses compared to the previous academic year, showing a healthy turn-over and dynamic adaptation.

2.2 Flexibility and Openness

At IMT Atlantique, breadth courses are a complement in the formal integrated curricula. They permit to add some flexibility to the relatively closed major & minor disciplinary integrated structure, and just like the liberal arts model, to offer openness and variety to fulfill students' curiosity. Maintaining a prominent place for breadth courses in curricula and granting credits for them, not only allows attracting students and clarifying their mind after intensive exam sessions, but also fosters transferable up-to-date skills for the benefit of the future engineer who will have to navigate in more complex professional environments.

The benefits of breadth courses can also be found at system and faculty levels: academics find educational spaces to echo their personal interests; lecturers or professors are given an opportunity to address smaller, more motivated classes and to test in a sandbox new pedagogical activities or partnerships (e.g. design with School of Arts, Geopolitics with Military Schools). Moreover, new thematic can be reactively incorporated in the curricula (e.g. big data, migrant crisis, terrorist attacks intelligence). Last but not least, breadth courses give academic developers a strong pedagogical liberty as regards learning style and often require smaller teaching teams.

Many competencies of the engineer are not merely based on knowledge or exclusively built on scientific or technical aspects. Nevertheless, introducing variety and flexibility in the course choices [11] requires some academic control, even as regards non-engineering courses, in order to ensure that programme or student outcomes (aka graduate outcomes) are achieved, in line with the most recent accreditation systems and national professional body's requirements, for purposes of transferability.

3 Teaching and Learning Activities for Transdisciplinary Judgment and Decision-Making Skills

The French *Grande Ecole* system is traditionally viewed as producing engineers with highly recognized management skills. The level of complexity for a future executive is supposed to increase with his/her level of responsibilities. In large project contexts, a decision-maker may face complex situations during his/her career with increasing responsibilities: he/she will be assessed on his/her ability to manage complexity and, in many companies, this criterion will have the same weight as other technical criteria, especially as regards managers. As a leader, the engineer is expected to learn "to put things in perspective" in order to keep a global vision of a situation and to manage it in the best possible way.

As defined by ENAEE (European Network of Accreditation of Engineering Education), Programme Outcomes describe "the knowledge, understanding, skills and abilities which an accredited engineering degree programme must enable a graduate to demonstrate" [4]. Programme outcomes areas are thus proposed to classify graduate or postgraduate engineering student outcomes (cf. 'a–k' of ABET or Eur-ACE criteria), e.g. Engineering Analysis, Investigations, Communication and Team-working, Lifelong Learning. For example, managing a complex project will require knowledge and understanding such as "critical awareness of the wider multidisciplinary context of engineering and of knowledge issues at the interface between different fields" [4], but also analytical skills such as "an ability to identify, formulate and solve unfamiliar complex engineering problems that are incompletely defined, have competing specifications, may involve considerations from outside their field of study and non-technical – societal, health and safety, environmental, economic and industrial – constraints; to select and apply the most appropriate and relevant methods from established analytical, computational and experimental methods or new and innovative methods in problem solving" [4].

This chapter explores how real in situ situations can be used as a form of experiential learning to prepare students to the engineering practice for which they must develop a "critical awareness of economic, organizational and managerial issues (such as project management, risk and change management)" [4], but also judgment making abilities defined by the ENAEE in 2016 as a core new Programme Outcomes area (among 10 core areas, as of today):

- to integrate knowledge and handle complexity, to formulate judgments with incomplete or limited information, that include reflecting on social and ethical responsibilities linked to the application of their knowledge and judgment;
- to manage complex technical or professional activities or projects that can require new strategic approaches, taking responsibility for decision making.

4 Active and Experiential Learning

As noted by Rouvrais, Mallet, and Vinouze [12] in 2010, many teaching & learning short activities have been designed to promote team work and experientially-based skills. Accordingly, "icebreakers, kick-offs, warm-ups, energizers, escape games; or brain-teasers are often used in student group activities" [13]. For example, at MIT, "short active learning games were introduced as activities to support formal classroom education. Polytech Singapore has proposed a One-Day One-Problem™ framework confronting students to a problem in order to generate solving skills" [12]. In the past few years, engineering education has extensively explored interpersonal and project management skills through PjBL, experiential or WBL models. Classically, project management skills are addressed in team based projects, with a focus on the selection and application of the most appropriate and relevant tools among established analytical, computational and experimental methods (e.g. WBS, GANTT and PERT tools, risks identification, analysis, and mitigation) [14]. But the engineering practice is not always fully rational and predictable, even when supported by methods and processes associated with risks analysis. Students may also need to be able to handle dynamic adaptation. Weick [15] suggested an approach to reach a higher level of reliability in the organizations by highlighting four sources of reliability and resilience: (i) respectful interactions between team members, (ii) a well-established system of roles, (iii) skills of improvisation and creative *bricolage* and (iv) an attitude of wisdom when facing a crisis situation. These four sources of resilience were assessed in another context by the French Naval Academy (*Ecole Navale*, located in Brest just like Telecom Bretagne) through nautical exercises aimed at stimulating these skills among cadets, as reliability represents a real stake in the Navy.

5 Navigation and Sea Risks Breadth Course Through Experiential Learning

Alongside the actual formal curriculum of IMT Atlantique which concentrates on large project management skills so as to address the aforementioned 2016 ENAEE decision-making skills requirements, the authors designed a breadth inter-semester course (specified INT164) in the form of a specific class of phenomenon [16] intended to develop students' ability to make decisions and react in unexpected and unpredictable situations. To this end, the experiential learning situations were selected to reflect real-life nautical scenarios with a high level of complexity and time pressure, likely to develop or reinforce specific skills such as risk and priority management, watchfulness, team management with respectful interactions, etc. It is to be noted that, although located on the sea-side, IMT Atlantique is a generalist IT and Energy graduate School of Engineering, and is not specifically oriented toward the sea or maritime sectors. Nevertheless, these nautical exercises constitute an opportunity for students, as future decision-makers, to learn collective mind, flexibility, and resilience with their team with a view to achieving reliability (which is profitable to any kind of organizations). These in-context and in-situ experiences are valuable in an engineer career where responsibilities are increasing (e.g. executives and decision-makers face complexity, uncertainty and urgency), especially in uncertain employment and career contexts. Moreover, a first student experience as a non-expert may create a learning-loop for future experiences and work-based situations, including improvisation [17]. It may also reinforce self-confidence through the early identification of transferable best practices.

5.1 INT164 Course Syllabus

As presented in Table 2, the “Navigation and Sea Risks” intersemester breadth course held in January 2016 was structured as follows: On the first day, 20 students were presented the context and the learning outcomes of the course, before introducing themselves and exposing their motivation and conceptions in relation to risk factors. Then, a 30-minute video of sea rescues was shown, including both inshore and offshore real stories and testimonials, with a focus on hypothermia factors. As learning activities, traditional maritime songs were also collectively used as warm-ups and team cohesion. Then, the students formed four teams of five persons each. The afternoon was dedicated to using safety maritime materials (e.g. life raft hitting, distress flare firing, dry and wet suit tests, etc.) on the shore. The teaching activities of the second day were more traditional and focused on the basics of coastal navigation tools and electronic support on board, while identifying factors of faults, errors, and failures. On the third day, the students went on-board to experience, in teams, several unexpected man over board scenarios, with resources such as a rubber dinghy, a 10.50-meter long (35 feet) POGO sailing boat and an OSCAR mannequin (as seen in Fig. 1). The tutors just observed the various exercises during 3 h per team, and never took part in decision and action processes. All the experiences were video recorded (two sessions took place, with two teams in the morning and two teams in the afternoon). In parallel, the other student groups prepared a coastal day navigation “on paper” for the coming week-end, either with a motor boat or a sailing boat, taking into consideration the various risks and factors they identified. The objectives (e.g. minimizing risks and maximizing pleasure) and resources were specified for the proposed navigation. On the fourth day in the morning, experiential feedbacks and videos were collectively analyzed in terms of factors identified and rules applied, and a return on experience was capitalized by the groups. A formal lecture then added theoretical foundations to the return on experiences (RoE).

Table 2. INT164 week agenda at IMT Atlantique.

	Monday	Tuesday	Wednesday	Thursday	Friday
AM	Course1: *Context, rescue videos, songs*	Course2: *Coastal navigation tools*	Practical2: *Man over board experiences*	Course4: *Retex & decision models*	Course5: *Meteorology*
PM	Practical1: *Experiential safety on board & materiall*	Lab1: *Marine electronics and reliability*	Project: *Navigation preparation*	Project: *Rescue protocol preparation*	Orals & presentations

Fig. 1. Students in action to rescue an OSCAR mannequin.

On this basis, each team of students prepared a formal rescue protocol (their “client” being the student sailing club of the institution) in the form of a poster, and realigned their navigation proposal for their crew. The last day started with a teaching session on local meteorology and forecasts, thermal winds, tides and streams, always with factor and reliability perspectives. The afternoon was devoted to an oral presentation of all the teams’ posters (i.e. protocol and navigation), assessment, and course evaluation. An online questionnaire was filled before the course to clarify motivation and profiles, so as to grasp qualitative data after the course.

The off-shore session took place in January, on one day, which is winter time in France, in a rather cold environment (10 °C, water at 10). The tutors attempted to pick a not too windy day so as to reduce any student over board risks. Conditions were reasonable in 2016 and did not impact student integrity.

5.2 First Cohort Background and Motivational Factors

The students at IMT Atlantique graduate School are aged between 19 and 23 y/o, most often without prior professional experience, with approximatively 17% of female students (as usually the case in French *elitist Grandes Ecoles* in engineering). In 2016, based on an online questionnaire filled by students (16 respondents over 20 participants, 5 females this year) one month ahead of the breath course, motivational factors were found to be mainly intrinsic, as showed in the following student quotes initially in French (to be read as 'I chose this inter-semester breadth course because'):

Motivation to discover a new environment	*'I love the sea environment'* *'I am passionate about the sea area'* *'I like sport catamaran and I find it nice to do sailing activities for a week'* *'I'm interested in the boating license'* *'I like anything that has to do with navigation and why not for the motor boat license and I think it's important to know the rules when boating'*
Motivation of curiosity	*'I never take time to go on the water during the year'* *'I do not live near the sea and it is a chance to do it'* *'I am motivated by curiosity and not by need'* *'Simply by curiosity'*

Some of the students had previous sea experiences, e.g. jet-ski, fishing with dinghy, surf, kayak, and windsurf. Among 16, two of them self-considered as experienced: (i) one occasional sailing instructor in a club, (ii) one junior beach lifeguard, (iii) one occasional regatta sailor. However, as shown in Table 3, half of the students had very few if none sea experiences: "*I have never been on the sea*", "*I only went on the Seine river for a dinner cruise in Paris*".

Table 3. INT164 student profiles regarding sea experiences.

Confirmed	Regular practitioner	Amateur	Novice	Complete novice
1	1	3	5	6

As expressed in the following student quotes, initially in French, the main difficulties anticipated or experienced by students in the first questionnaire were:

Due to personal factors	*'I still have a lot of difficulties and self-confidence problems, and I got seasick on a nautical trek and I hope that this intersemester breadth course will help me to overcome this evil'* *'I do not know if I can get seasick or not, but I want to participate anyway'* *'During a night at anchor, weather conditions rapidly degraded to be very bad, the small boat in which I slept drifted to take us in an oyster park. The person with me managed the crisis well and there was only minor damage, but I was not able'*
Due to natural external factors (e.g. tides)	*'Mismanagement of the tide to sail out of bay. We knew it would be just at the start but we went there (and back with the help of the engine…). I knew we would have a problem to return back to port. After this event, I am more comfortable to say "no" to a navigation program if I consider it not reasonable'* *'Surf session in South West of France, 2km drift by the current before reaching the beach. Need to learn to stay calm'* *'A very dangerous tidal pool gave me trouble getting out of water'*
Due to resource external factors	*'Some difficult situations in my summer sailing lessons thanks to the famous Murphy's Law (broken stuff, crew in the water, etc.) but nothing too dangerous due to the presence of instructors'*

6 Analysis

For qualitative analysis purposes, data sources were derived from a second online non-compulsory questionnaire to be filled by the students, right at the end of the course. The sample permitted to analyze 75% of the students cohort (n = 15 over 20). The form included Likert scale questions so as open questions. A vast majority of students considered that they had sufficient prior knowledge and experiences to participate in this course, confirming that it was 'introductory' in nature and to be classified as a breadth course. The only prior warnings made in some courses were about jargon and nautical terms (a memo or index required).

Table 4. INT164 student post-motivational viewpoints.

Pedagogical variety	Motivational factors
'*It changes from what is done daily in engineering schools while remaining relevant to our training (in particular the leadership course following the sailing trip)*'	'*Yes. That was exactly my expectations. I am totally novice, of course, but I love the sea and sailing too*'
	'*Yes, it is a pleasure to learn about the world of sailing!*'
	'*I think this week was very interesting. Security has always interested me (internship discovery among firefighters, first aid) so it seemed interesting to discover a new environment and new life conditions*'
'*It was great. […] This is a special experience and we had the opportunity to work in a group in an environment quite different from what we are accustomed*'	'*Yes!!!! I am very glad I chose this intersemester. To be more comfortable on the Pogo/catamaran later and for my culture and profession (meteorology, leadership)*'
	'*Great atmosphere, very interesting immersion*'
	'*I learnt a lot. I enjoyed the outdoor activity of Wednesday, the mood of the Monday songs*'

6.1 Motivation

When answering the question "*Was this breadth course a good choice*", students provided some motivational factors, as presented in Table 4 (quotes initially in French).

Table 5. Student viewpoints on INT164 values.

Knowledge and skills	Confidence and efficacy
'*discovery and understanding of several new marine concepts*'	'*the atmosphere was really nice, I was not ridiculous to fail in my attempts to rescue the poor Oscar*'
'*learned a lot of things to know, save a MOB, steer a sailing boat, use a VHF, prepare a navigation*'	'*the human exercise at sea was difficult for 2 person with the Pogo. We had finally realized the risks that may be encountered in the open sea*'
'*we learn the necessary safety measures in case of emergency*'	'*things learned for myself reported my lack of relevance in an emergency*'
'*I have learned a lot, especially on leadership and the need to properly allocate roles on board*'	'*regarding MOB situation operation, even by having knowledge, when you find yourself in a situation without crew briefing/procedure, we realize that the manoeuvre is not obvious*'
'*it allowed me to discover this aspect of resourcefulness and leadership skills, "debrouille" and decision making, autonomy in the context of navigation*'	

6.2 Knowledge and Skills Perceived Development

When asked "*What do you value in the experiential rescue activity*?", the students pointed to knowledge and skills, but also identified some emotional factors such as efficacy, as presented in Table 5 (quotes initially in French).

6.3 Open Personal Student Perspectives

An open question "express yourself" permitted to collect free comments from the students. Apart from messages such as 'thanks' and 'keep this breadth course for next year', some comments evidenced the transferability of the knowledge and skills related to the course, i.e. (quotes initially in French):

- *'I intend to travel further offshore, this intersemester helped me to know general safety at sea';*
- *'it was very nice for me personally because I have gained new knowledge that will be helpful to me that summer because I will cruise one month in Egypt';*
- *'I liked this intersemester. I learned many things, I even had the desire to develop a professional sea activity. I was already fishing on the shore, I want to try fishing in coastal waters';*
- *'I had no idea yet on a future work or profession, and I think it helped me'.*

7 Student Assessment and Formalized Skills

The experiential scenarios proposed to students in the INT164 breadth course are based on researches relating to high reliability, formalized by the University of Berkeley, in order to better understand the normal functioning of High Reliable Organizations (HRO). Their purpose is mainly to identify the characteristics of HRO and to explain their exceptional performance. Unlike the other theoretical frameworks on Reliability (e.g. Theory of Normal Accidents, Theory of Crisis), HRO theoretical frameworks [18, 19] are close to the Actionists ones [15]. They both investigate reliability through human behaviors identified as a source of reliability. Moreover, they underline flexibility in the decision-making process. For instance; Weick identifies three characteristics of the HRO: (i) information overload, (ii) constant turbulence, (iii) increasing complexity. These characteristics are opportunities to activate a sense making process. They were used as theoretical foundations to implement the rescue scenarios during the experiential sessions of INT164.

Overall, the feedback analysis sheds light on internal and external motivational factors and transferable skills. It is worth noting that through this experience, several students developed self-confidence in their (i) ability to grasp complex situations, (ii) ability to adapt dynamically to unexpected situations, and/or (iii) ability to act in an uncertain context with judgment, as formalized by the dedicated ENAEE core learning area.

Table 6. INT164 assessment criteria for the navigation proposal.

Criteria
weather, tides, waves, and currents rigorously taken into account;
estimation and control of the boat characteristics
analysis and management of uncertainties, critical mind;
priority management and focus points;
risk factors identification according to the crew experiences;
key success factors identification;
judgment and decision-making;
overall reliability and persuasiveness.

7.1 Assessment Criteria in 2016

The student assessment was based on two presentations made by each teams, followed by a peer assessment and a faculty assessment on the same learning items. The criteria taken into account for assessing the oral presentations of the navigation proposal are presented in Table 6.

The rescue protocols presented, via posters, by each student team, based on their on-board experience, include rules, but their presentation remains unclear, as will be explored hereafter. Also, students failed to define meta-rules, as expected by the authors.

7.2 Meta-Rules for Appropriate Decisions in Complex Environments

For purposes of addressing the challenge of making relevant and appropriate decisions in complex environments, the concept of meta-rules was presented to students during the Thursday course session, following the collaborative RoE. The concept of meta-rules appears in various research fields, such as education, business research, and entrepreneurship [20]. Meta-rules correspond to one form of meta-level knowledge, and Davis [21] defines them as rules governing a set of lower-level rules, constituting a framework of rules for which the priorities might change. The main advantages of meta-rules are as follows:

- to enable decision makers to gain an overview of the managed entity (e.g., service, organization) which is required for future leaders;
- to improve reliability by avoiding decision errors, which may lead to a degradation of the capacity of a system, a service, an organization to achieve its objectives.

More recently, based on this approach, Le Bris [17] explored whether the use of meta-rules might improve the efficiency of a complex decision-making process. Her conclusions reveal that in complex situations, for non-experts (i.e. the majority of the students concerned in INT164), introducing meta-rules in a decision-making process provides greater reliability than the mere use of rules. This point is still discussed between the HRO promoters and the Actionists, the later considering that the strict respect of rules can be a source of danger [15], while the former defend it is a source of greater safety. But the use of meta-rules offers a modality to resolve this theoretical tension and also the tension between "learning" and "performing" in complex situations.

8 Conclusion

The future of engineering and engineers in relation to smart society is under pressure in a rapidly changing world [22], where engineering programmes have to constantly adapt to meet new societal challenges. Engineering can be seen as the act of utilizing the output of science and technology to create safety and prosperity for all humanity. For this, renewed skills and competencies, maybe more than mere degrees, are important in the job market. To instill more reactivity in engineering training and education, it is therefore critical to ensure flexibility in programme architecture styles. In the hope of inspiring faculty and deans willing to renovate their engineering programmes so as to better respond to their stakeholders' needs and global socioeconomic development challenges, breadth courses were discussed in this chapter as a mean to introduce such a flexibility and reactivity into integrated engineering programmes, in a French context sometimes too strongly coupled for outcome-based education requirements. Flexibility is valued both by the students who are pressing for larger course choices, and by the educational system which requests higher dynamicity and openness to support course variety and offers. As a complement to mere static majors, minors, or semester-long project activities, the innovative breadth course model presented in this chapter relies on highly motivated faculty members, small class sizes with targeted guidance, fully dedicated resources, and even sometimes outdoor real in-situ experiential activities, as exemplified in this chapter. For extension purpose, the Navigation and Sea Risks breadth course frame and objectives may be used as a significant stone in the future foundations of a framework of multi experiential breadth courses aimed at developing decision-making skills (e.g. underwater, air, mountain, forest), as required in 2016 by the European accreditation body.

Based on a qualitative feedback analysis, the authors showed that student self-confidence, self-efficacy and thus motivation for the overall curriculum can be enhanced through breadth courses. Some future work on qualitative analysis is maybe to investigate, by analyzing age and gender figures, with course environmental constraints (e.g. weather, time of the year), to allows us to observe if motivation levels are affected by these factors. This analysis should now be assessed quantitatively on the basis of the questionnaire results obtained in connection with all breadth courses conducted in 2016 within the institution.

With activities aligned with the most recent programme outcomes as required by accreditation bodies, breadth courses can reinforce students' abilities, in a performance-based approach to multidisciplinary and transdisciplinary competencies. In order to be prepared for a smarter society but in VUCA environments, engineering students are to be equipped regularly with new skills and attributes. As analyzed in this chapter, the learning outcomes on judgment and decision-making skills were only partially met in the presented course for the 2016 session. For example, the concept of meta-rules was not addressed by the students in their rescue protocol deliverable, thus confirming a low abstract conceptualization. Nevertheless, in the short term, this Navigation and Sea Risks course is to find an echo in the semester projects (PjBL model) of the formal curriculum, where team working, project and risk management skills are already under focus via more classical and rational decision analysis processes. For the engineering practice, a comprehensive understanding of innovative and applicable techniques and methods of analysis and investigation is foundational, but will also tell us more about their limitations for new trends in graduate education on decision-making skills.

For the 2017 session, following a learning loop including Concrete Experience, Reflective Observation, Abstract Conceptualization and Active Experimentation [23], the Navigation and Sea Risks breadth course designers have decided to challenge more specifically the reflectivity of students while on board (e.g. using videos as in 2016, but also white boards for in situ briefings and debriefings). The objective is to work on instant conceptualization skills through collaborative sessions about risks, to explore more dynamically the concept and implementation of rules, and to ignite more aptly inferred meta-rules during the various experiential scenarios. The engineering students' perceptions of soft and non-technical skills, industry expectations, and career aspirations [24] may also be realigned with real-life experiences for decision-making purposes. In the medium term, the ability to adapt to unexpected situations and the knowledge of rules transferable thereto may also find an echo in a context which is not always fully rational, such as future student interviews (e.g. internship or first job offers), as French graduate engineering accredited Schools mostly rely on a Work-based Learning model also [25].

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Characteristics of Student Centred Learning from the Perspective of Engineering Lecturers

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Abstract. Student Centred Learning (SCL) approach is recommended worldwide in higher education. However, many engineering educators are reluctant to shift from teacher-centred to SCL approach because they perceive that effective teaching must heavily involve lectures and knowledge must be transmitted to the learners by the lecturer. This research seeks to identify engineering lecturers' perspective on the characteristics of meaningful learning. The characteristics are compared to SCL characteristics as outlined by the How People Learn framework. Using data collected among engineering lecturers over two years at the beginning of training workshops on SCL conducted in various universities throughout Malaysia, the data is analyzed qualitatively using thematic analysis. The results show the positive characteristics mentioned are SCL-related approaches, proving that SCL is a relevant teaching and learning approach in engineering because it is not only recommended by experts but also concurred by engineering lecturers when seen from their own learning perspective.

Keywords: Student-centred learning · Faculty development · Training

1 Introduction

The demand of high quality engineers today forces higher education institutes to reform engineering education (Latucca et al. 2006). With the advent of the fourth industrial revolution, engineering programs cannot afford to remain stuck with curricula and teaching and learning approaches prevalent in the twentieth century. In addition to the requirement in knowledge and developing thinking and other skill sets such as communication, team-working, etc., the 21st Century also requires holistic development of students. The Global Competitiveness Report 2016 – 2017 published by the World Economic Forum (Schwab 2016) predicts that the most important skill required in 2020 is complex problem solving. This is in-line with the current requirement of the Washington Accord for accreditation of engineering programs among institutions from member countries (International Engineering Alliance 2015).

One of the major shifts in engineering education today to develop relevant engineering graduates is moving from teacher centred learning to student centred learning (SCL) (Duderstadt 2008). However important unanswered questions remain, and concerns about implementation continuously arise whenever lecturers attempt to bring

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SCL to reality. The US National Doctoral Program Survey (Weibl 2001) showed that science and engineering lecturers are not equipped with effective teaching skills, especially SCL. Although academic staff had been groomed to conduct research during their studies, there was hardly any training in how to effectively teach and design a conducive learning environment. As stated by Ambrose and Norman (2006):

When it comes to teaching, most faculty members enter the academy as "well-intentioned gifted amateurs".

The shift towards SCL and sustaining the approach over time, is by no means a simple task (Radzali et al. 2013). There are many barriers to SCL implementation in higher education, such as (Bonwell and Eason 1991):

- influence of educational tradition
- lecturer's perception on teaching and learning and their roles
- uneasiness of changing and implementing something new
- lack of incentive for change

Lecturers' perceptions are rooted in their belief on teaching and learning. SCL approaches follow the current educational paradigm or learning theory that knowledge is actively constructed by the learners, not passively received from the teachers (Felder 2011). This educational philosophy, coined as constructivism, is not new. Nevertheless, this philosophy is not easily accepted by engineering educators, especially those who were predominantly trained under a different educational philosophy when they were students, resulting in conflicting beliefs when they were encouraged to implement SCL (Kolmos 2002).

Institutions of higher learning often provide training courses on various SCL approaches to support lecturers in developing the skills needed. Since the lecturers' perception towards teaching and learning is an important barrier to overcome in encouraging lecturers to implement SCL after attending the training courses, it is important to find out what engineering educators believe in effective or meaningful learning, before asking them to reflect about what they actually do to teach, and whether their teaching activities lead to effective learning.

The Universiti Teknologi Malaysia Centre for Engineering Education offers a series of SCL training workshops, starting with the simple and not so highly student-centred techniques on active learning/Informal Cooperative Learning for engaging learning in the first workshop, then on team-based learning using Cooperative Learning, and finally the highly student-centered approach of Problem-based Learning (PBL), as shown in Fig. 1. The duration of each workshop is two days, and the PBL workshop is conducted in two, two-day workshops. Participants are given a workbook (Mohd-Yusof et al. 2016a) that has been designed using constructivist principles which they fill in as part of their learning process to construct their own understanding during the workshop. There is normally a gap of two to three months between the workshops so that lecturers can learn to implement the knowledge and skills in their courses, before moving on to the subsequent more student-centered and more complex approaches. This will also allow participants to discuss their attempts in their courses on the approaches learned in the previous workshop when they come to the subsequent more advanced training workshop. The Active Learning Workshop have been

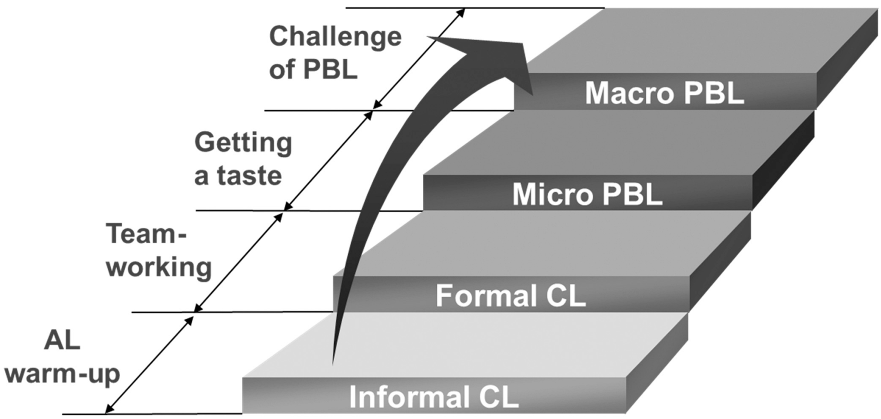

Fig. 1. Gradual change in training towards student-centred teaching and learning implementation

conducted in institutions of higher learning throughout Malaysia and other countries, such as India, Afghanistan, Korea and Turkey.

This paper describes a study that was conducted among participants of the Active Learning Workshop to determine the meaning of effective or meaningful learning from their perspective when they were learners in a formal learning environment. The SCL framework referred to in this research is based on the "How People Learn" (HPL) Framework (Bransford et al. 2000). The qualitative data collected were thematically analysed according to the HPL framework.

2 The How People Learn Framework

Bransford et al.'s (2000) "How People Learn" framework can be utilized for designing learning environments through four overlapping lenses illustrated in Fig. 2, which are knowledge centred, learner centred, assessment centred and community centred. The framework is a meta-analysis of strong research and theories that explains the conditions that help people to learn. The HPL framework can be used as a guide in developing an effective learning environment. On the other hand, the lenses can also be used as criteria for evaluating the effectiveness of an existing learning environment, which can then be further improved.

The lenses overlap one another, as shown in Fig. 2. Being knowledge centered is to support learners understand and learn knowledge that is organized with interconnections to the fundamentals of the discipline. Being learner centered is to take into account learners' background, pre-conceptions, existing knowledge and skills, etc., to create meaning for motivating learning. Being assessment centered is to provide opportunities for feedback to learners, not only through formative assessment by the instructor, but also from peers to help them gauge their current performance and improve. Being community centered is to provide a safe and supportive learning environment that promotes a community among students and faculty members,

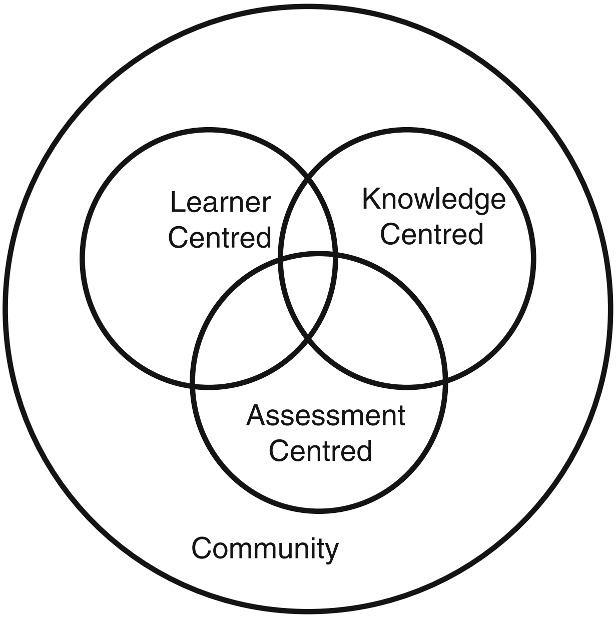

Fig. 2. The how people learn framework (Bransford et al. 2000)

developing a sense of belonging and bonding among them, which in turn creates an environment that is conducive for all to participate in the learning process.

Based on the HPL framework, a learning environment that can foster effective learning has four aspects that focus on learners, knowledge, assessment and community. SCL promotes the learning environment mentioned earlier where the focus of learning is on the learners, that the learners know the learning goals, that the assessment are to improve the learning and that people learn from each other (Bransford et al. 2000). Engineering educators still resort to teacher centred learning because this was the way that they were taught. To create paradigm shift or change in teaching conception cannot be easily done through training (Kolmos 2002). Therefore, we ask engineering educators to reflect and to see learning from the perspective of learners at the beginning of the workshop. The aim is to identify the characteristics of both teacher centred and student centred learning among the engineering educators from their perspective when they were learners in a formal setting.

3 Methods

This is a qualitative research study that employed open-ended questionnaire to understand what the engineering educators believed about the best and worst teaching styles or methods. Qualitative data provides rich information for researchers to understand in depth the belief, perception and thought of the participants. This is achieved by using qualitative data analysis methods to produce rich description of a phenomenon (Mohd-Yusof et al. 2015).

In this study, the data was collected among engineering lecturers over a period of two years during the beginning of training courses on SCL conducted in various public and private colleges and universities throughout Malaysia. In total, nineteen training courses were conducted which involved approximately 30–40 educators in each training. Each training participant was asked to write down their most meaningful formal learning experience, and their worst formal learning experience. The sample of the questionnaire is published in (Mohd-Yusof et al. 2016a). These were then collected and discussed with all other participants in the training. The data is analyzed qualitatively using thematic analysis. Later, the themes are compared to the characteristics of SCL based on the How People Learn framework.

For data analysis, thematic analysis technique was conducted. Thematic analysis technique is useful in organizing qualitative data through detail examination and recording of patterns (or themes) within the data itself (Braun and Clarke 2006). The process of coding is to develop the patterns or themes by capturing or recognizing the important points in the data. The codes were interpreted by reviewing the co-occurence, comparing the data, codes or themes, and finding the relationships between the themes. The analysis can be performed inductively or deductively. In another words, it can be data-driven or theory-driven. In the first case, the aim of the analysis is to explore new phenomenon through the data only while the second case is to understand a phenomenon through a preconceived framework. In this study, the analysis is deductive in nature, where the themes are based on the How People Learn framework.

In this study, there are six steps in thematic analysis (Braun and Clarke 2006) which are:

1. Get familiarized with the data
2. Generate initial codes
3. Search for themes
4. Review the themes
5. Define and name the themes
6. Produce the report

The researchers get familiarized with the data by reading all the texts. Codes were given to each sentence based on the HPL framework. For example, one-way communication, hands-on learning, etc. They were then divided into two themes which are student-centred and teacher-centred approaches. The themes were reviewed based on the data and the How People Learn framework.

4 Results and Discussion

The lecturers recalled that their worst formal learning experiences occured when they were in school, as well as in university. The result shows that the characteristics of the worst formal learning experience perceived by the engineering lecturers are:

1. One-way communication
2. Chalk and talk
3. Passive learning

4. Spoon feeding and preparing students for examination
5. Emphasis on memorization – rote learning
6. Teaching without informing the objectives
7. Examinations not aligned to the teaching

The results indicate that the worst formal learning experience can be classified as teacher-centred, where the lecturers or teachers did not seem to consider the students as learners, focusing instead on what is most convenient for themselves. The learning is passive using lecture, chalk and talk and in one-way communication, without informing the students of the learning objectives. The examinations are not aligned with the teaching and students are prepared to pass examination through spoon feeding and memorization. The lecturers often reported negative emotions that comes along with these worst formal learning experiences, showing that they do not only affect learning, but also demotivate the learners from the subject being taught. These are what happened under the traditional one-way lecture approach in teaching in engineering education which Felder (2012) stated:

> *For anything but simple factual knowledge that can be learned by rote memorization, direct transmission of information that students absorb and understand in its entirety simply doesn't happen.*

The alternative is the emerging approach to view and understand teaching and learning is through the constructivist approach subscribed by the "How People Learn" framework.

Similar to the worst learning experience, the lecturers recalled that their most meaningful formal learning experiences occured when they were in school, as well as in university. Based on the data gathered, the characteristics of the most meaningful formal learning experience perceived by the engineering lecturers are:

1. Two-way communication
2. Hands-on learning and projects
3. Experiential learning
4. Use of real world & industrial examples
5. Group discussions
6. Peer learning/teaching
7. Feedback on learning tasks & assessment
8. Relate teaching with the previous knowledge
9. Use of visual aids and incorporate site visits

When the characteristics are mapped to the HPL framework, it can be seen that the characteristics of favourable learning experience perceived by the engineering lecturers are those that relate to the student-centred approaches to learning. Most of them indicated that they can vividly recall the exact topics and experience that they went through when relating their meaningful learning experiences. Some of the characteristics were mentioned by a few reports in engineering education as best practices in educating future engineers (Duderstandt 2008; Spinks et al. 2006) such as learner-centred, team-based problem solving approach, etc.

The results indicate that as learners, engineering lecturers found it meaningful to be engaged in the learning environment, such as being involved in hands-on learning, having discussions with their peers and the instructor, going for site visits and experiential learning. The lecturers found real world examples and problems, as well as having their instructors provide support in making connections with prior knowledge effective for learning. They associated these meaningful experiences with positive emotion, that encouraged them to become better learners.

Learners remember more if they had gone through meaningful learning experience such as participating in discussions and going through the real experience like site visits. These learning experiences are useful in developing professional skills (Mohd-Yusof et al. 2016b) that will increase the employability of the engineering graduates. These meaningful learning experiences also motivate and retain the interest of learners on the subject being taught, encouraging them to invest more effort to learn beyond what is required. These findings are consistent with past research on SCL approaches (Prince 2004; Dale 1946).

Table 1 shows the classification of the characteristics favourable to learning that corresponds to the lenses in the HPL framework. As seen from Table 1, each of the characteristics may be mapped to at least one (and two for some) HPL lens. Some may be mapped to more than one, because the lenses can actually overlap, depending on the characteristic. For example, “group discussion” is under assessment centred because this allows students to receive feedback on their ideas from their peers. Group discussion also falls under community centred, because it develops the students into a learning community that can help and support each other in learning. The same goes with “relate teaching with previous knowledge”, which can be mapped under knowledge centred and learner centred lenses.

Table 1. Classification of meaningful learning characteristics to the HPL lenses

HPL Lens	Characteristics of meaningful/effective learning from the engineering lecturers
Knowledge	Hands-on learning and projects, relate teaching with previous knowledge, use of real-world and industrial examples, experiential learning
Learner	Relate teaching with previous knowledge, two-way communication, experiential learning
Assessment	Feedback on learning tasks & assessment, group discussion
Community	Group discussion, peer learning/teaching, two-way communication, two-way communication

Comparing the characteristics of the worst and the meaningful learning experiences, lecturers’ preferences as learners tend to gravitate towards SCL approaches as defined by the HPL framework. None of the negative learning experience can be classified under the HPL lenses; in fact, all of them are focused toward the instructor or the teacher, without any consideration on the learners. This shows that as learners, engineering educators do agree that SCL approaches are indeed powerful in creating meaningful learning, while teacher-centred approaches are not beneficial, and is a major turn off for learning. Unfortunately, when the role is reversed, most engineering educators tend to forget this, and more often choose to follow how they were predominantly taught, which is to just use the teacher-centred approach, rather than use the approach that they actually prefer as learners. This may be linked to what Bonwell and Eason (1991) said about lecturer's perception on teaching and learning and their roles. Thus, in training and mentoring engineering educators in SCL approaches, it is helpful to remind them of their own experiences as learners so that they may strive towards making the learning environment in their courses effective as prescribed by the HPL framework.

5 Conclusion

From this study, it can be concluded that SCL teaching and learning approaches produce positive outcomes in engineering education. Engineering lecturers should reflect on their own formal learning experiences to improve their teaching because what they perceive to be the effective learning process should be translated into their teaching methods in their courses. This is important because what they do in their courses will have far reaching impact in attracting, retaining, and developing the much needed future engineers who can face up to the challenges of the 21^{st} century.

Therefore, the shift from teacher centred to SCL is the right way forward in engineering education as promoted by Engineering Accreditation Council (EAC 2012). However, the shift cannot really successfully occur because overcoming the barriers also require support at the institution level. Nevertheless, the findings in this study provides administrators and trainers the important information on the favorable view of SCL from the perspective of engineering lecturers as learners, which should be brought up in convincing them to take the first step towards developing the skills and implementing SCL in their courses.

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A Virtual Learning System in Environmental Monitoring

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Abstract. This paper provides an overview of a Learning Enhanced Watershed Assessment System (LEWAS) and its public interface called the Online Watershed Learning System (OWLS). These systems provide access to environmental monitoring case studies that are developed based on high frequency water and weather data from a small urban watershed on the campus of Virginia Tech (VT) and represent applications of the innovation cycle of engineering education research and practice. The development of LEWAS was motivated by a programming learning unit in a first-year engineering class in 2008, and since then it has grown into a unique research and education lab on the VT campus. Several examples of learning activities based on the LEWAS/OWLS are provided and applications of these systems within and outside VT are discussed. Results of a pilot study to track the OWLS' users are provided and this work is expected to provide guidelines to develop personalized learning systems in environmental monitoring. Interdisciplinary collaboration facilitated by the LEWAS/OWLS work has resulted in a several new NSF awards, and examples are provided.

1 Introduction

Since its founding in 2008, the Learning Enhanced Watershed Assessment System (LEWAS) has grown from a student activity in a first year engineering course at Virginia Tech (VT) into a continuous real-time watershed monitoring system on a $\sim$3.0 km^2 urban watershed that drains a part of the VT campus (Delgoshaei 2012; McDonald et al. 2015c). This system has been used in at least 26 different undergraduate and graduate courses at 8 community colleges and universities across 3 continents including 15 courses in 5 colleges at VT (Dymond et al. 2013; Delgoshaei and Lohani 2014; McDonald et al. 2014b; McDonald et al. 2015a, c; Basu et al. 2015; McDonald et al. 2016; Brogan et al. 2016; Brogan 2017). Briefly, the LEWAS monitors at a high frequency (1–3 min.) water and weather parameters including water quantity, specific conductance, pH, turbidity, dissolved oxygen, water temperature and weather data. These data and associated case studies are available to users through the Online Watershed Learning System (OWLS). In order to advance this multifaceted system, the LEWAS team benefits from faculty and graduate and undergraduate students from diverse backgrounds including engineering education, civil and environmental engineering, electrical and computer engineering, mechanical engineering, chemical engineering, computer science, biological systems engineering, industrial

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design, environmental science, and biology. The development and implementation of the LEWAS/OWLS has been supported by multiple grants from the US National Science Foundation.

The development of the LEWAS has closely followed the innovation cycle of educational practice and educational research (Jamieson and Lohmann 2009). This cycle keeps evolving as our team develops and implements creative instructional activities, facilitated by the LEWAS/OWLS, leading to our research activities. Our earlier work (McDonald et al. 2015a) showed an older version of this cycle which has since been modified and is shown in Fig. 1. Boxes 3, 5, and 7 show doctoral level research in engineering education that is supported at the LEWAS lab. Box 3 shows the first doctoral dissertation that initiated the LEWAS concept by implementing the initial version of this high frequency lab and evaluating the effectiveness of the LEWAS-based learning experiences in a freshmen engineering course. Details are provided in our prior publications (Delgoshaei 2012; Delgoshaei and Lohani 2014). Successful implementation of the lab into a freshman engineering course motivated our team to develop a proposal to the U.S. National Science Foundation for seeking resources to introduce the LEWAS into a senior level hydrology course in the civil & environmental engineering department at VT and into freshman engineering courses at a Virginia Western Community College (VWCC) near VT. Details of this work are given in our prior publications (McDonald et al. 2014b; McDonald et al. 2015a, c). These activities led to another PhD dissertation (box 5) resulting in development of the OWLS and application of the LEWAS/OWLS beyond VT at national and international levels and assessment of its effectiveness in student learning and motivation (McDonald et al. 2015b; Brogan et al. 2016; Brogan 2017). This work motivated our team to start working on tracking the use of the LEWAS/OWLS at various geographical locations, and some results are discussed later in the paper. This tracking

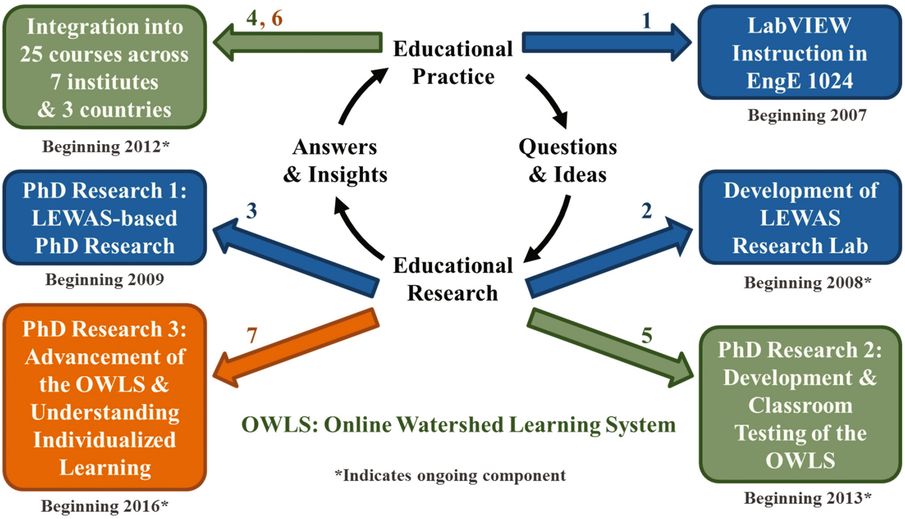

Fig. 1. Innovation cycle leading to the Online Watershed Learning System (OWLS)

work is leading to another PhD dissertation (box 7) and the goal of this research is to investigate individualized student learning facilitated by the OWLS (Brogan et al. 2017). Beyond engineering education, the LEWAS data has also been used by graduate students in civil & environmental engineering and other majors. As of this writing, 3 PhD students (2 in engineering education (Delgoshaei 2012; Brogan 2017) and 1 in civil & environmental engineering (McDonald 2016)) and six masters' students (five in civil & environmental engineering and one in crop & soil environmental sciences) have used the LEWAS data directly and graduated from the lab. In addition, 13 undergraduate researchers have been engaged in research as a part of an NSF supported Research Experiences for Undergraduates (REU) Site (Basu et al. 2016).

The objectives of this paper are to: (i) provide a brief overview of the LEWAS and its public interface called the Online Watershed Learning System (OWLS), (ii) discuss examples of LEWAS/OWLS-based case studies/learning activities that have been introduced in a variety of courses within and outside Virginia Tech (VT), and (iii) discuss findings of the OWLS' users tracking work that is implemented to identify groups of students using the OWLS at VT and elsewhere and future research activities. The overall goals of the research presented here are to provide examples of practical research to practice and to show that these results can be applied across a wide selection of learners.

2 Literature Review

The innovation cycle of educational practice and educational research, proposed by Jamieson and Lohmann (2009), is a model that can be used to describe iterative innovations in educational practice that are informed by educational research and iterative advances in educational research that are informed by educational practice. As we have journeyed through these innovation cycles, we have adopted different theoretical frameworks for advancing the research at different stages including the expectancy value theory of motivation (Wigfield and Eccles 2000; Delgoshaei 2012; Delgoshaei and Lohani 2014), situated learning (Greeno et al. 1996; Johri et al. 2013; Brogan et al. 2014; McDonald et al. 2015b; Brogan et al. 2016; Brogan 2017), Bloom's revised cognitive taxonomy (A Committee of College and University Examiners 1956; Brogan et al. 2014; McDonald et al. 2015a, b; Brogan et al. 2016; McDonald 2016; Brogan 2017), Jones' MUSIC Model of Academic Motivation (Jones 2009; McDonald et al. 2015b; Brogan et al. 2016; Brogan 2017), active learning (Faust and Paulson 1998; McDonald et al. 2014b; McDonald et al. 2015a, b, c; McDonald 2016; McDonald et al. 2016), experiential learning (Warren 1995; Delgoshaei 2012; Brogan et al. 2016; McDonald et al. 2015a; McDonald 2016) and engagement theory (Stark and Lattuca 1997; Brogan et al. 2017). In the remainder of this section we briefly describe a few of these that apply to the present research.

The OWLS has been designed using the framework of situated learning. According to situated learning, knowledge is "distributed among people and their environments" (Greeno et al. 1996, p. 17). Situated learning can be subdivided into sociocultural and sociocognitive traditions (Johri et al. 2013). OWLS research to date has focused on the sociocognitive tradition of situated learning, which says that learning is dependent on the learner's environment. Within this framework, the OWLS situates learners at the LEWAS measurement location virtually using visual imagery and watershed background information and maps. The success of this virtual situating at the LEWAS site depends on how the OWLS user mediation interface (Lindsay et al. 2007) impacts the presence of the users, where presence is "the subjective experience of being in one place or environment, even when one is physically situated in another" (Witmer and Singer 1998, p. 225). In order to assess the impact of LEWAS/OWLS-based modules on students' learning, Bloom's Revised Cognitive Taxonomy (A Committee of College and University Examiners 1956) has been used to generate quantitative learning questions at different learning levels (Brogan 2017). Likewise, for impacts on students' motivation to learn, Jones' MUSIC Model of Academic Motivation (Jones 2009) has been used.

In our most recent LEWAS/OWLS-based activities, we are using the theoretical framework of experiential learning. Experiential learning theory suggests an "orientation towards teaching and learning that values and encourages linkages between concrete educative activities and abstract lessons to maximize learning" (Warren 1995, p. 239). Educational environments building on this theory encourage students to engage in real world problems where they can reflect on their learning experience and what is being learned (Kolb and Kolb 2005). These experiential learning experiences can include hand-on activities in the classroom, field site work, laboratory experiences, indoor and outdoor projects and internships and cooperative education placements (Odera et al. 2015). By engaging in these learning activities, students can directly apply their acquired knowledge and skills in a real-life context, which furthers helps in developing transferable skills (Beard and Wilson 2006).

Students' engagement with the learning activities can positively impact their learning (Stark and Lattuca 1997). Thus, by measuring students' engagement with the experiential learning activities, can provide an idea about the effect on learning. Engagement can be of three types: behavioral, emotional and cognitive (Fredricks and Blumenfeld 2004). As suggested by Kuh (2009), time on task can be a measure of behavioral engagement. Class attendance has been commonly used in traditional classrooms as a quantifiable term for time on task (Douglas and Alemanne 2007). On the other hand, for cyberlearning systems, the variable to measure time on task can be the time a student spends interacting with the system (Beer et al. 2010). This can be measured using the digital traces that their interactions with the system leave behind.

We have found in our implementations that a combination of theories are needed for a given learning module implementation. Several of those listed here were used in the implementations described in Sect. 3.3 below with active/experiential learning driving activity development, situated learning driving interface design, engagement theory driving the collection of anonymous user tracking data and Bloom's revised cognitive taxonomy and Jones' MUSIC model of academic motivation driving assessment of learning and motivation, respectively.

3 Results

3.1 History of Development

The foundation of the LEWAS was laid in a programming learning activity in a 1st year engineering course in 2008 at VT. The goal of this learning activity was to show the real world applications of this programming software that has strengths in data acquisition. An urban stream that has water quality issues was chosen to deploy a few water quality sensors and the goal was to bring real-time water (quality and quantity) data to classroom with the help of this programming software and associated hardware and wireless technology. This 1st year learning activity experiment has now grown into a full-fledged research and education lab (i.e., LEWAS and OWLS). Figure 2 shows the overall planned data flow process in the LEWAS lab. A Raspberry Pi computer is used to communicate with the various instruments used to collect the water quantity (flow meter), water quality (water quality sonde) and weather (weather station) data that is sent over the campus network to a MySQL database running on a server on campus. The OWLS then accesses this data along from the server. The ultrasonic level transducer for water quality and the rain gage have been installed and will be connected at a later date. Due to limitations of the current setup, the video data currently follows a parallel path to the OWLS and is not integrated into the database. Several of our prior publications provide details on the development and application of the LEWAS/OWLS (Delgoshaei 2012; Dymond et al. 2013; Brogan et al. 2014; McDonald et al. 2014a; Basu et al. 2015; McDonald et al. 2015c; Basu et al. 2016; Brogan et al. 2016; Brogan 2017).

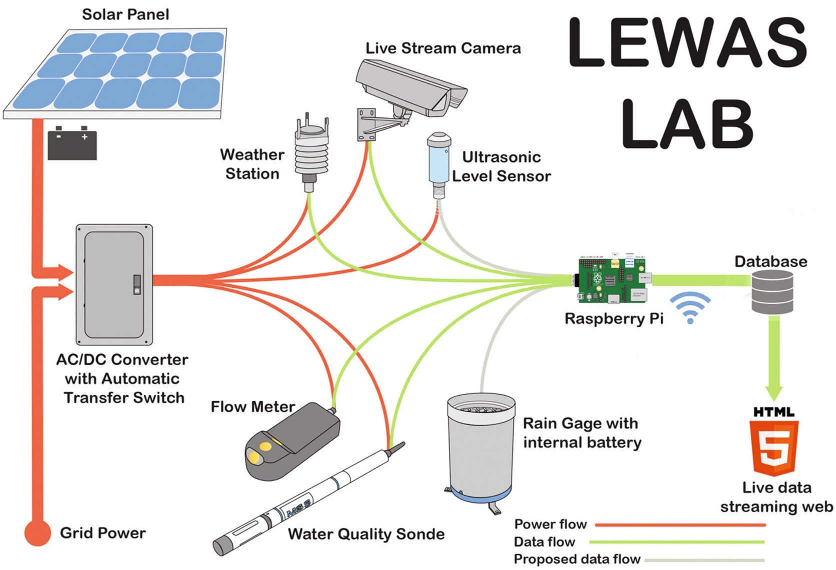

Fig. 2. LEWAS data flow diagram

3.2 Use of the LEWAS/OWLS at Virginia Tech and Elsewhere

In parallel with the evolution of the LEWAS/OWLS during the past 8 years, educational use of the LEWAS/OWLS has been growing rapidly during this time both at VT and at institutions across the United States and in India and Australia. Figure 3 shows growth of the LEWAS/OWLS activities built around the ongoing innovation cycles of educational practice and engineering education research. One area of growth occurs through partnerships between faculty at various institutions and members of the LEWAS team. This allows LEWAS/OWLS-based learning activities to be implemented into these faculty members' courses. Examples of such activities are described in the following section. These activities allow LEWAS/OWLS learning to branch out to new institutions, and sharing data about these implementations helps to inform the innovation cycle. Additionally, some of these institutions are in the process of installing their own LEWAS-style systems, and sharing data between these monitoring systems will allow students to study data from multiple types of watersheds. This interconnected learning system disseminates fruit in the area of research by reaching other academics via publications, in the area of education by reaching students via courses and in the area of service by reaching the public via outreach programs.

In order to support the growth of LEWAS/OWLS-based learning activities, we are developing creative 'water-related' case studies based on data we observe at the LEWAS site. These case studies can be related to both naturally occurring events, e.g., thunderstorms, and anthropogenic events, e.g., chemical spills. One recent anthropogenic event

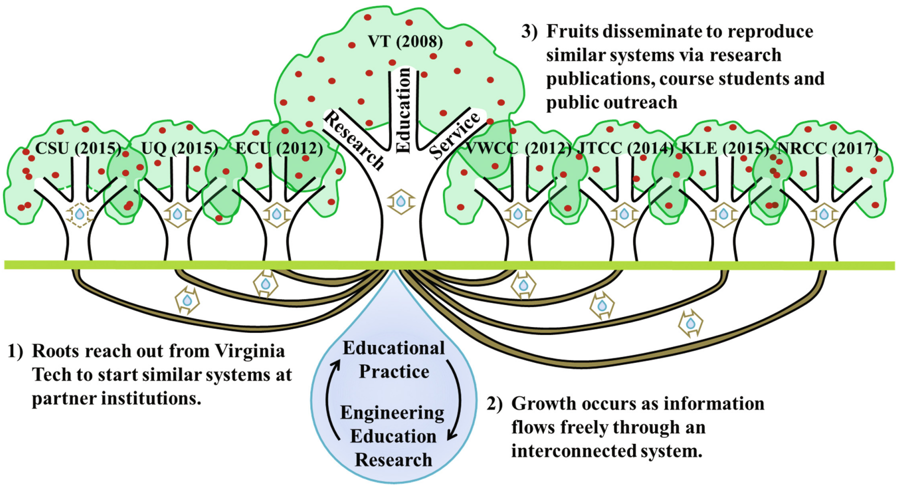

Fig. 3. Growth of the Learning Enhanced Watershed Assessment System (LEWAS)/Online Watershed Learning System (OWLS) through Education, Research and Service (2008 – present) at CSU: Central State University (Wilberforce, OH, USA); UQ: University of Queensland (Brisbane, Australia); ECU: Eastern Carolina University (Greenville, NC, USA); VT: Virginia Tech (Blacksburg, VA, USA); VWCC: Virginia Western Community College (Roanoke, VA, USA); JTCC: John Tyler Community College (Richmond, VA, USA); KLE: KLE Technological University (Hubballi, India); and NRCC: New River Community College (Dublin, VA, USA)

that we observed on Sep. 21, 2016 impacted the water quality such that pH increased to 11.2 (normal value: ~8.1) and specific conductance rose to 8300 μS/s (normal value 700–800 μS/s). This event (http://lewaspedia.enge.vt.edu:8080/videos/stroubles1/20160920/stream_20160920_160001.webm) lasted for a few hours caused an unusually large downstream migration of crayfish. We are still investigating the possible causes with the help of facilities people on VT campus. Once our investigation is completed, this event will turn into a case study and becomes a part of case studies available through OWLS page (www.lewas.centers.vt.edu/dataviewer/) and we believe such case studies will promote real world problems-based learning opportunities. The following case studies have been described in our prior papers: summer thunderstorm (McDonald et al. 2015c), winter storm salt wash (Clark et al. 2015; Brogan et al. 2016; McDonald et al. 2015c; McDonald 2016) and water main breaks (Dymond et al. 2013; Brogan et al. 2016). Recently, we have been adding video case studies that combine video and monitoring data for various events. These case studies allow users to see the visual impacts of an event, e.g. precipitation, water level and water turbidity, in the camera's video next to a graph showing changes in key environmental parameters during the course of the event (Fig. 4). One such natural event case study occurred on Sep. 28, 2016 when a small amount of hail fell in the watershed. The melting hail caused relatively constant decline in the water temperature in the steam long after the storm precipitation had ended. This was followed by relatively constant water temperature increase back to the pre-event level.

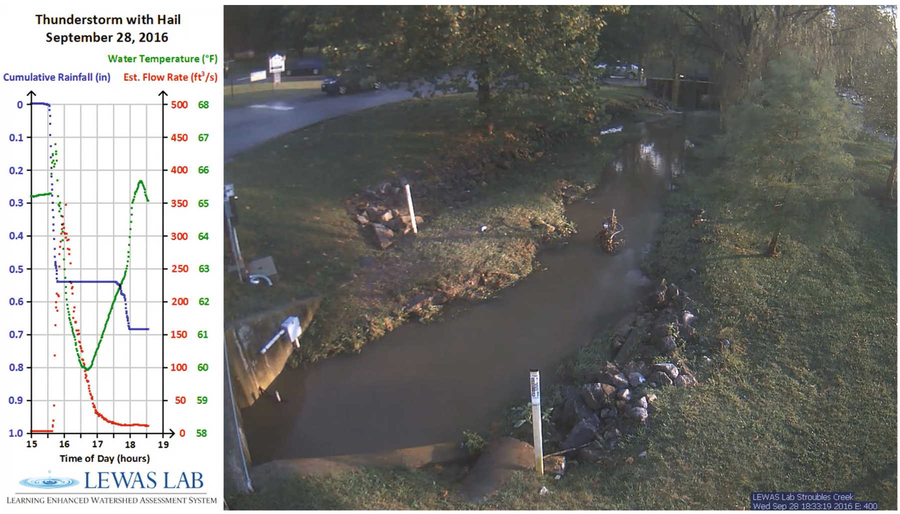

Fig. 4. Screenshot from the thunderstorm with hail video case study (https://www.youtube.com/watch?v=d_m7JhoKXak)

3.3 Examples of Recent LEWAS/OWLS-Based Learning Activities

In this section we discuss examples of various learning activities that we implemented into a diverse collection of courses at VT and elsewhere during the past 2 years. Additional learning activities are described in our prior publications (Delgoshaei 2012; Dymond et al. 2013; Delgoshaei and Lohani 2014; McDonald et al. 2014b; McDonald et al. 2015a, c; Basu et al. 2015; McDonald et al. 2016; Brogan et al. 2016; Brogan 2017). For assessment of these activities, we have adapted standard techniques for assessing remote labs, including measures of students' learning, self-perceived learning and motivation. Examples of formal research designs with quantitative and qualitative results are described for several of the additional learning activities in the papers listed above. Similar approaches were used for the activities described in this section. However, due to IRB requirements, the assessment results of the current activities are not presented here.

3.3.1 Learning Activity in a Freshman Engineering Course at Virginia Tech, Virginia, USA

In the spring of 2015, the LEWAS team developed and assisted in implementing a 7-week long project for the freshman engineering course (EngE 1216) at VT. This is an introductory engineering course, and students are challenged to work in a project based learning (PBL) environment to solve an engineering problem (Prince and Felder 2006). Course instructors act as facilitators. More than 1400 freshman engineering students worked on this LEWAS-based project. Students were expected to: (1) learn about the VT campus watershed, the way it is affected during storm events and its implications to the stream habitat, (2) develop the ability to work with real-world noisy data, (3) conduct data analysis to identify unusual water quality events, and (4) develop a MATLAB program to conduct basic rainfall-runoff analysis. Students were asked to develop a decision support system using MATLAB to analyze extreme water quantity and quality events, followed by a project presentation and submission of a final report. Students analyzed high frequency (1–3 min sampling period) water quantity and quality data from several storm events recorded at the LEWAS site to evaluate the flooding potential in the Webb Branch watershed and characterized the quality of the stream habitat based on the water quality parameters. The LEWAS team provided technical help and trained various instructors for implementing this project.

3.3.2 Learning Activity in a Computer Science Course at Virginia Tech, Virginia, USA

In the fall of 2015, LEWAS team members worked with a faculty member from the computer science department to develop a four-week long LEWAS-based project for a junior level data structure and algorithm course (CS 3114). The major goal of the project was to give students the opportunity to do computation in the context of environmental monitoring. Similar to the learning activity described above, the project helped the students to solve and handle a real-world problem with noisy data from their local watershed. For this project, students were given a water quality and a water quantity data file having records from a past storm event at the LEWAS site. Students were asked to use the water quality and quantity data to implement a B+tree data structure. At the beginning of the project, LEWAS lab members gave a presentation to introduce the LEWAS and project to the class. Students accessed the OWLS and LEWAS websites for more information. More than 90 students worked on this project either individually or in pairs.

3.3.3 Learning Activity in a Crop and Soil Environmental Science Course at Virginia Tech, Virginia, USA

In the spring of 2016, the LEWAS team developed and implemented a four hour long LEWAS-based learning activity in a water quality class in the crop and soil environmental sciences department. This activity included an in-class hands-on activity which was followed by a field visit to the LEWAS site. The goal was to provide the students with an understanding of the functioning of the LEWAS, i.e., how water quality and quantity sensors collect the data, how the data is acquired from the sensors by a Raspberry Pi, and how it is transmitted and stored in a database to be accessible through a user interface. Firstly, an overview of the LEWAS was provided, and its basic components including the functionality of Raspberry Pi was explained. Then the process of data flow from the sensors to the user interface was explained. Secondly, LEWAS members facilitated a hand-on activity in which students developed their own temperature monitoring system by assembling a temperature sensor with a Raspberry Pi, a python program, a computer monitor and other hardware to read a continuous live stream of temperature data on their monitors. Thirdly, students visited the LEWAS field site to observe the physical connections of the system and to compare and analyze the differences between this complex system and the simple temperature monitoring system they made in the classroom. In order to examine sensitivity of the sensors, students added a bucket full of ice water to the stream and were able to see a dip in water temperature by accessing the OWLS on their smart phone at the field site. This activity helped students to get a better understanding of how computer science and engineering disciplines like computer, electrical and civil engineering are linked to their environmental science field. Around 30 students participated in this activity. It may be noted that this was the first time such an activity was implemented into this course and the head of the department was present in the class along with the course instructor. A video of this activity was later uploaded to the department's website to share this experience with others in the department and elsewhere. This activity will be repeated in the spring 2017 semester.

3.3.4 Learning Activity at KLE Tech, India

Our team was invited to conduct a one-week engineering education workshop in June 2015 at this university. The goals of the workshop were to (1) share experiences of developing and implementing active and collaborative learning activities into a first-year engineering course at VT with KLE Tech faculty, (2) provide assistance in developing active and collaborative learning activities for a first-year engineering course at KLE Tech, (3) initiate a project to develop a counterpart of the LEWAS lab at the KLE Tech to support the first-year program, and (4) leverage experiences from the first-year engineering program into other courses a KLE Tech through a spiral curriculum approach. Twenty-five faculty participated in this workshop. Few sessions were devoted exclusively to the discussion of the LEWAS and OWLS. Various water monitoring data and case studies accessible through OWLS were made available to the faculty. Details of the workshop and outcomes are discussed in our prior publication (McDonald et al. 2016). The KLE Tech faculty has since successfully developed and implemented a first-year engineering course called Engineering Exploration into their curriculum. More than 1500 engineering freshmen have completed this course as of this writing. Students have an opportunity to access the OWLS remotely to analyze high frequency water data.

3.3.5 Learning Activity at the University of Queensland, Australia

In collaboration with our colleagues at the University of Queensland (UQ), Australia, we implemented a learning module into the tutorial portion of an introduction to environmental issues course taken by about 100 second year civil engineering students. In this module, students were introduced to the LEWAS/OWLS via a pre-tutorial and asked to analyze a set of five events that occurred during a 6 day period and determine, based on data and imagery, which event was which. Students were asked to support their decisions using the environmental and visual data provided. This activity used skills similar to those used in video case studies. This activity also included estimation techniques for use in calculating the rainfall-runoff coefficient. In the tutorial session, after the activity had been completed, the students engaged in faculty-led group discussions of their results. The primary goal of this learning module was to introduce students to the use of real-time, high-frequency data in environmental monitoring and to encourage them to think about what types of conclusions about cause and effect could or could not be made from such data.

3.3.6 C2GEN Course

Or team was invited to develop an online learning module by the organizers of the C2GEN, a Chautauqua program for the 21st century. This NSF-sponsored program offers top-quality professional development opportunities to STEM faculty around the globe and helps in the dissemination efforts of the NSF. Further, it also offers an opportunity to assess various delivery mechanisms for large scale, effective faculty professional development—face to face, synchronous online, and asynchronous online. Our team developed and implemented a course in summer 2015 which focused on the development of the LEWAS and its application at VT and VWCC. Learning modules covering 20 h of instruction time included the basics of water quantity and quality monitoring, integration of LEWAS sensors (water quantity, quality and weather), computing hardware, software and power, by highlighting the LEWAS. Each module within this course is asynchronous and self-contained. Topics covered include watersheds, water quantity and quality issues in a small urban watershed, environmental sensors and their calibration, software-hardware interface, quality assurance, and examples of classroom modules.

3.4 Tracking OWLS' Users

One method of assessing how users are interacting with the OWLS during learning modules is to store/log the digital traces that they leave behind when they use the OWLS (Brogan et al. 2016; Brogan 2017; Brogan et al. 2017). This information allows us to monitor the paths that users take through the OWLS, how long they spend using various components of the OWLS and how frequently they return. These data can be used to measure students' engagement with the learning modules (Brogan et al. 2017). In 2015, anonymous user tracking was integrated into the OWLS using Google Analytics and universally unique identifiers (UUIDs) as a pilot test in order to obtain the digital traces required to assess student engagement with the OWLS. Although this approach is limited by being unable to track users across web browsers and devices, it does provide some valuable data for a group of users from an individual course. In order to separate the page views into groups of users, the following 15 different digital traces were recorded: the UUID, the UTC time at page load in ms, the local URL, the user's current country, region (e.g., state) and city, the device category (e.g., desktop, tablet, mobile), the operating system and version, the browser and version, the screen resolution, the internet service provider (ISP), the referring website, and if the next webpage viewed by the user was outside of the OWLS (Brogan 2017; Brogan et al. 2017). Using these traces, each user (UUID) was assigned to a user group and given a user ID within that group. After removing known LEWAS users from the data, the remaining users were identified using their cities and use or not of academic internet service providers (ISPs). If a known user appeared in more than one of these groups, this user was assigned to the highest ranking group that he or she appeared in according to the following list: (1) LEWAS, (2) VT ISP, (3) other Blacksburg region, (4) VWCC ISP, (5) other Roanoke region, (6) Floyd County High School (FCHS), (7) John Tyler Community College (JTCC), (8) Piedmont Virginia Community College (PVCC), (9) other Virginia region, (10) East Carolina University (ECU), (11) Central State University (CSU), (12) Marquette University (MU), (13) other US region, (14) KLE Technological University (KLE Tech), (15) other India region, (16) University of Queensland (UQ), (17) Brazil and (18) other international.

During the period from Oct. 9, 2015 through Dec. 20, 2016, there were 18,521 page views from the 18 user groups (Table 1). Page views are an approximate measure of the levels of engagement that various groups of users have with the OWLS. However, not all user groups used the OWLS in the same way. For example, LEWAS team members had a regular background presence with at least a few views nearly every day. However, user groups representing students in a single class often used the OWLS for only a few days at a time and did not return. This can be seen in Fig. 5. For example, students from the KLE Tech course above appeared from Mar. 29 to Apr. 4, 2016, and students in subsequent courses at KLE Tech appeared from Oct. 17–25, 2016. Likewise, students in the course at UQ appeared from Apr. 16–19, 2016. This method of grouping students starts to break down when students from several courses at the same institution use the OWLS during overlapping time periods. This was the case for the students in the Crop and Soil Environmental Science course at VT. This learning module overlapped with 4 other courses that semester at the same institution. Note that there were several days during the spring 2016 semester (Fig. 5) when VT users

Table 1. OWLS user groups and corresponding number of page views listed according to the assigned ranking used for assigning users to groups

Rank	User group	Number of page views
1	LEWAS	5,898
2	Virginia Tech (VT) Internet Service Provider	1,289
3	Other Blacksburg region	5,176
4	VWCC Internet Service Provider	1,642
5	Other Roanoke region	356
6	Floyd County High School (FCHS)	116
7	JTCC	480
8	PVCC	2
9	Other Virginia region	476
10	East Carolina University (ECU)	4
11	Central State University (CSU)	1
12	Marquette University (MU)	65
13	Other US region	517
14	KLE Tech	1,597
15	Other Indian region	129
16	University of Queensland (UQ)	584
17	Brazil	79
18	Other international	110

showed increased use of the OWLS, but it is not possible to know which users at VT are from which course unless other details of user patterns are investigated. Knowing that an activity was completed in-class during specific hours is one possible way to isolate overlapping courses at a single institution. However, in the case that these course periods also overlap, as was the case at VWCC during Oct. 2015, patterns in user page views can be used to cluster users from different courses (Brogan 2017).

4 Conclusion

The LEWAS and OWLS are good examples of the implementation of the 'research to practice cycle' in the context of engineering education research. Readers are encouraged to consider similar 'real world' problems on their campuses or neighborhoods to explore opportunities to engage students in creative learning opportunities. This work has clearly demonstrated the research to practice aspect of engineering education research activities. Furthermore, the applicability of this work across a wide range of learners has been demonstrated. We are now developing a user tracking system that will help us to analyze the learning behaviors of various users of the LEWAS/OWLS. This work will be a step in the direction of developing a personalized learning system in environmental monitoring. We are also exploring virtual reality and augmented reality applications to enhance the learning potential of the LEWAS/OWLS. Also, it may be noted that this work has provided several opportunities to develop interdisciplinary collaboration

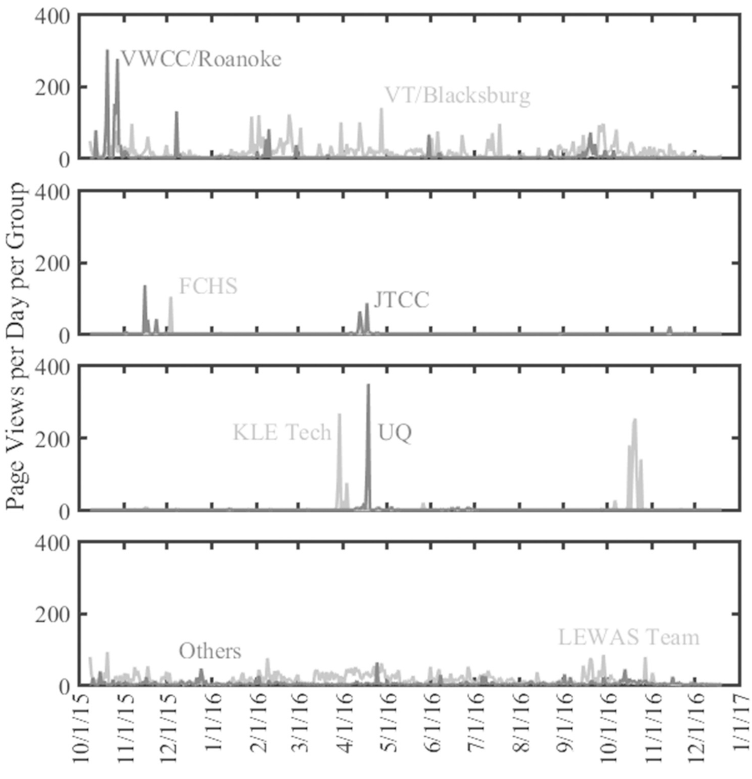

Fig. 5. OWLS page views per day by user groups from Oct. 9, 2015 through Dec. 20, 2016

within and outside VT. For example, the LEWAS lab has been hosting a Research Experiences for Undergraduates (REU) site on interdisciplinary water science and engineering for more than 6 years which has engaged more than 20 interdisciplinary faculty from 5 different colleges at VT. Eighty-five REU scholars have graduated from this site since 2007 and this site has been renewed for another 3 years (2017–2020). This work has also resulted in a new Research Experiences for Teachers (RET) site on WaterECubeG, hosted by the LEWAS Lab, which brings together interdisciplinary faculty to train 30 teachers from 9–12 grades and community colleges from south-west Virginia in interdisciplinary water science research. These teachers are expected to introduce these research experiences into their courses to introduce 9–12 grades and community college students to critical water research issues. Successful implementation of various LEWAS/OWLS-based learning activities both within and outside VT has also facilitated an I-Corps L award from the NSF which is the first award of this kind at VT and activities to explore commercial application of the LEWAS/OWLS is in progress at the time of this writing. Since fall 2016, the indoor part of the LEWAS lab has expanded into the premises of an interdisciplinary research institute at VT called the Institute for Critical Technology and Applied Science (ICTAS) and experiential learning activities facilitated by the LEWAS/OWLS will aid in developing similar learning activities for other ICTAS labs.

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