OUTCOME-BASED CIVIL ENGINEERING CURRICULUM DEVELOPMENT

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ABSTRACT

Malaysia seeking to be a full member of the Washington Accord has led to the Engineering Accreditation Council (EAC) of Malaysia to give emphasis on outcome based curriculum. Although the EAC manual published in 1999 listed the generic attributes for graduates, no effort was made to ensure engineering schools to embrace and implement it. The prescriptive mode of evaluation continued until recently where engineering schools are expected to describe their programmes according to outcomes. The Malaysian Engineering Education Model (MEEM) was paving the way for engineering schools in 2000 on outcome-based education as well but again the spirit of MEEM was not understood well or there was no compulsion to follow. Beginning 2004 the interest in Outcome-based Education (OBE) began to emerge with several engineering education providers leading the way to it. Universiti Putra Malaysia (UPM), which believes strongly in MEEM is no exception and began revising its programme curriculum to adopt OBE approach in 2004. This paper describes the iterative approach taken by the Department of Civil Engineering UPM in redefining its programme objectives and identifying the programme outcomes and expounding on the course learning objectives. The programme emphasizes on providing strong engineering sciences and mathematics competencies with transferable skills either embedded within the professional courses or as individual courses. On this competency block an in-depth and advanced niche competencies are built. All these are mapped against the 13 developed programme outcomes adapted from EAC and Accreditation Board of Engineering and Technology (ABET) attributes. The paper also provides some examples of the outputs from the curriculum review workshop that could be used to develop an engineering curriculum.

***Key words**: Outcome based, Civil Engineering Curriculum, Curriculum Development, Learning Objectives*

INTRODUCTION

Currently, Malaysian universities are on the verge of undergoing a cultural change in their curriculum development to apply the "outcome-based" learning instead of prescriptive teaching. The Quality Assurance Department at the Ministry of Higher Education had developed a guideline for public universities to check the quality of programmes offered with outcome-based emphasis. However, the engineering education sector has its own champion steering the way towards the outcome-based education (OBE), and that is the Engineering Accreditation Council (EAC), under the purview of the Board of Engineers Malaysia. These moves are in line with the paradigm shift in the education sector worldwide to OBE.

EAC had began to introduce the OBE concept with the 11 generic attributes, adopted from the Engineers Australia accreditation system, in its first published manual in 1999. However, the rationale of the attributes were not fully understood or practiced by the engineering education providers as the emphasis in the manual was still prescriptive. Staff-student ratio, number of graduation credits and duration of programmes are among the 'bean counting' that the manual stressed, as quantitative evaluation is more objective and easily understood and satisfied by the providers. Curriculum development by the providers thus followed the traditional approach with slight modification to include course objectives in the syllabus content. Assessment methods still remain orthordox with assignments, tests, and final examinations being dominant.

EAC as a provisional member of the Washington Accord now has to reflect embracing OBE fully before being accepted as a permanent member possibly in 2006. EAC is now undertaking a study to identify the outcomes suitable for Malaysia and then proceed to revamp its manual to provide clear guidelines for its panel and the providers of engineering education. The cultural change to full OBE is not without problem, as the knowledge of OBE is relatively poor among the providers. This has not dampened the zeal of several engineering departments to take the lead in designing their curriculum towards OBE. The Department of Civil Engineering, Universiti Putra Malaysia (UPM) for example has paved the way to produce an OBE Civil Engineering curriculum during its recent review. This paper describes the approach taken at UPM when reviewing the Bachelor of Civil Engineering (BE Civil) programme that incorporates OBE.

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ROUTE TO CURRICULUM DEVELOPMENT

In early years curriculum development at the Department of Civil Engineering was conducted by first agreeing on the curriculum structure, which also specifies the allocation of teaching credits. Staffs within the same sub-discipline then deliberated on the contents of the syllabi for the respective sub-disciplines. Minimal intregration was done to ensure that gaps between the sub-disciplines were closed. It was essentially a sub-discipline centred exercise. The varied sub-disciplines external examiners and assessors that were appointed to evaluate the programme were expected to tighten the loose screws and close the gaps. Later came the Malaysian Engineering Education Model which looked critically at the way engineering curriculae are developed. It encouraged curriculum developers to see curriculum development as a process approach and grouped the curriculum into six categories, namely, scientific, professional, industrial, global and strategic, humanistic, and practical skills and competencies. The Model calls for engineering curriculum that is able to produce graduates with scientific strength, professional competency, multi-skilled, well-respected and potential industry leaders, as well as morally and ethically sound. However, it allows flexibility in the curriculum, where one may choose to strengthen the scientific competencies and therefore less emphasis on the professional courses.

The current BE Civil curriculum at UPM [1] which is based on the Malaysian Engineering Education Model (2000) [2] and the Engineering Accreditation Council Manual [3] is undergoing its eighth revision and expected to be implemented in 2005. The Department took upon itself to introduce OBE in the new curriculum despite the vagueness in the interpretation and acceptance at the national level. It began with providing awareness on OBE amongst the academic staff at the department. A series of seminars by "internal experts" were conducted among which were OBE overview, course learning outcomes, problem-based learning, project-oriented learning, cooperative learning and the Malaysian Engineering Education Model. The exposure was expected to allow academic staffs to understand and embrace the concept of OBE before undertaking the review proper at a three-day workshop.

Although a draft eighth revision BE Civil curriculum [4] had been produced based from the feedbacks from a series of meetings conducted since January 2004 by the following entities: teaching staffs; external assessor (Prof. John B. Burland from Imperial College, UK); advisory panels from the industry; and students, participants at the workshop were told to reserve all judgment and the sub-discipline that they represent but focus on the graduates abilities to produce, be it short or long term. The workshop was organized with the following objectives:

a) Review programme objectives
b) Identify programme outcomes
c) Develop curriculum structures based on broad areas (group of courses within the same sub-disciplines or inter-related topics) that take into account the programme objectives and outcomes.
d) Develop broad areas outcomes that take into account the programme outcomes and the teaching and assessment methods.

As OBE was introduced the first time during this curriculum review proper, this exercise was basically an experiential learning process. Debates on definitions and interpretations on OBE continued despite earlier exposure to it. This created greater awareness and understanding of OBE among the staffs and facilitated the running of the workshop.

DEVELOPMENT OF PROGRAMME OBJECTIVES

The Department approached the development of the programme objectives through an iteration process as shown in Figure 1.0. A paper by Felder and Brent [5] was also used as a guide especially with the terminologies and examples of OBE. It began with a brainstorming session which identifed three major constituencies or stakeholders of the programme comprising: accreditation bodies (EAC and ABET), potential employers (consulting and construction companies, government agencies, research institutions, institution of higher learning, developers, manufacturing and sales companies) and non-governmental organizations (may include professional and non-professional organizations). Their requirements were interpreted based upon the relevant documents [3],[6],[7] and role play as stakeholders. The objectives must also be in line with the vision of the School. Faculties also kept in view of the other stakeholders identified which were parents and general public, alumni, and students.

The School envisions as a leading institution for the advancement of engineering in the world, and sets its missions [8] to:

a) Develop the art and science of engineering for the well-being of mankind
b) Educate engineering students to high standards of scientific, managerial and professional competence in harmony with the environment.
c) Share their knowledge and skills with communities throughout the world.

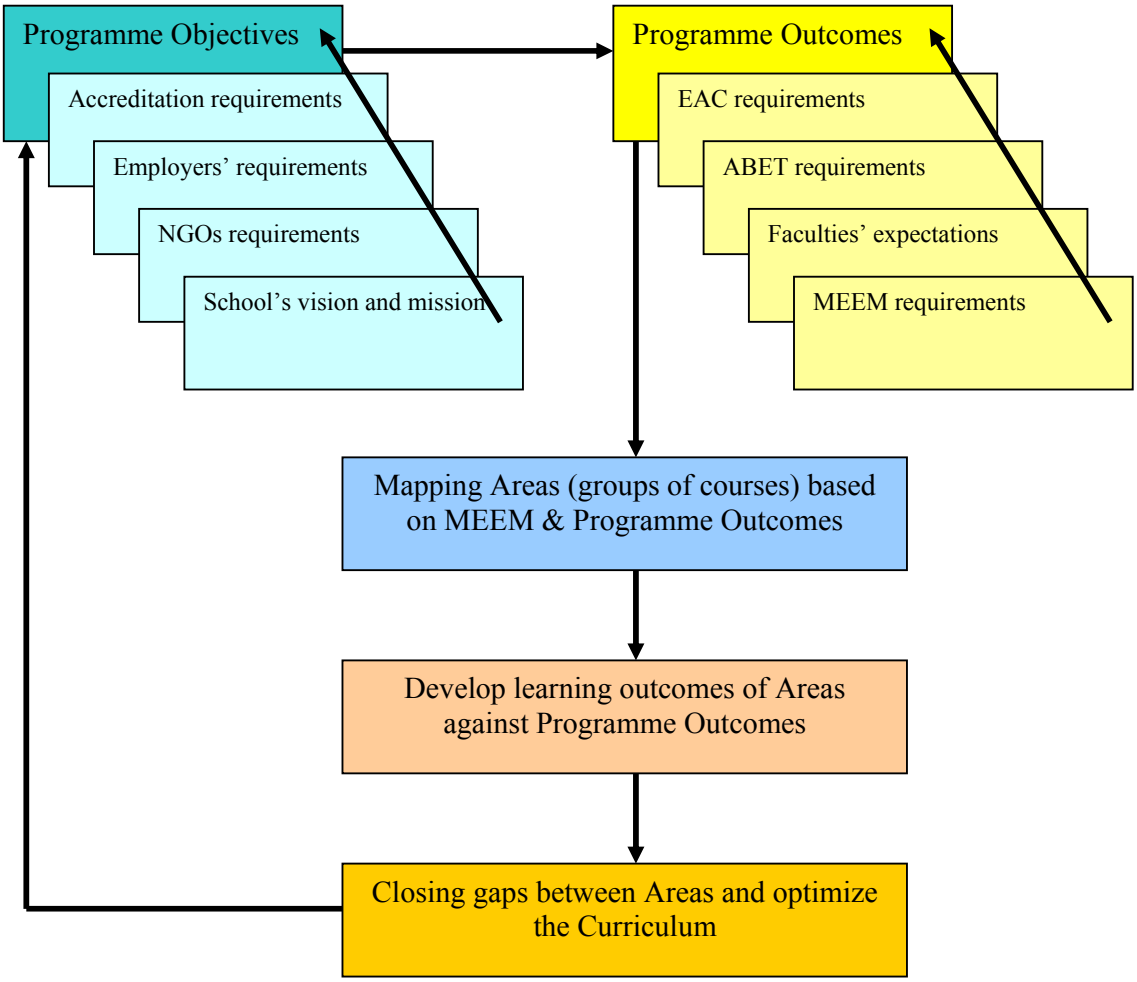

Figure 1.0 Development Concept of Outcome-based Education

In line with the vision and missions of the School and the 'expectations' of the stakeholders the following programme objectives were formulated:

a) To produce graduates with sufficient knowledge in different areas of civil engineering and possess the necessary skills for work in the industry.
b) To produce graduates who are sensitive and responsible in the social, cultural and the environmental context.
c) To produce graduates for work in advanced design and innovation at international level.

Table 1.0 provides the explanation of the keywords used in the programme objectives as well as measurable elements in order to avoid different interpretations in the future.

Table 1.0 Explanations to keywords in programme objectives

Keywords in the objectives	Explanation and measurement
….. for work in industry.	Majority of the graduates will find jobs in civil engineering industry (consulting and construction companies, government agencies, research institutions, institution of higher learning, developers, manufacturing and sales companies).
…. possess the necessary skills ….	Skills include communication, interpersonal and technical skills. The attainment of this objective may be indicated through the feedbacks from employers and alumni.
…. Sensitive and responsible towards social, cultural and environmental context.	Graduates are expected to understand the professional ethics and will solve engineering problems considering all the three aspects.
…. work in advanced design and innovation at international level	• Advanced design and innovation are niche areas that require strong scientific and professional competencies. • At international level is an indication of activities that are not routine or projects managed by multinational companies. • This may be indicated by a number graduates (or percentage) working in advanced design projects, or R&D institution or multi-national companies.

DEVELOPMENT OF PROGRAMME OUTCOMES

Programme outcomes state the attainment of students' abilities, which the Department has to ensure that the stated outcomes are achieved before they are allowed to graduate. The workshop participants debated on which basis the outcomes should be developed. As there was already the EAC generic attributes available and the move by EAC to be a Washington Accord signatory, it was felt that EAC and ABET outcomes should provide a good basis for refining the brainstormed outcomes. The following 13 programme outcomes that cater the requirements of EAC and ABET (reference of the respective outcome by the two bodies is in the bracket that proceeds the listed outcomes) were agreed upon:

1. Ability to apply knowledge of mathematics and engineering sciences. (EAC-4.2a) (ABET-3a)
2. Ability to design and conduct experiment as well as analyse and interpret data. (ABET-3b)
3. Ability to design a system, component or process to meet the design requirement. (EAC-4.2e), (ABET-3c)
4. Understanding principles of sustainable design and development. (EAC-4.2f)
5. Ability to function effectively as an individual and in a group with the capacity to be a leader or manager as well as an effective team member on multi-disciplinary teams. (EAC-4.2h)(ABET-3d)
6. Ability to identify, formulate and provide creative/innovative/effective solution to the problem. (EAC-4.2d),(ABET3e)
7. Understanding of professional and ethical responsibility. (EAC-4.2g)(ABET-3f)
8. Ability to communicate effectively with engineers, other professionals and community at large. (EAC-4.2b), (ABET-3g)
9. Broad education necessary to understand the impact of engineering solutions in societal, cultural, global and environmental context. (EAC-4.2i),(ABET-3h)
10. A recognition of the need for and ability to engage in lifelong learning. (ABET-3i)
11. Knowledge of contemporary issues (related to engineering that no other educational experience could provide). (ABET-3j)
12. Ability to use necessary skills, techniques and modern engineering tools for civil engineering practice. (ABET-3k)
13. Ability to meet challenges in special designs and constructions.(EAC-4.2c)

Each programme outcome must not contain too many required abilities, as it would make mapping the outcome to course learning objectives to be difficult to achieve. As an example, a programme outcome that requires *ability to design a system, component or process to meet the design requirements incorporating sustainable design and development* is difficult to be applied to a basic design course such as in reinforced concrete design. It is interesting to note that ABET's criteria are relatively easy to adopt or adapt as each programme outcome addresses a specific issue and measurable.

IDENTIFICATION OF AREAS TO SATISFY PROGRAMME OUTCOMES

There could be a tendency for participants to push for their sub-disciplines to be heavily considered within the curriculum. In this session participants were asked to be independent and reserve their judgement when coming out with the areas (or group of courses) to be covered in the curriculum. Participants were also reminded that transferable skills should not be ignored when considering these areas. Competencies and skills proposed by MEEM (2000), as shown in Table 2.0, which had been adopted by the present curriculum was used as the basis to identify the appropriate areas.

Table 2.0 Competencies and skills proposed by the MEEM (2000) [2]

1. Global and strategic	Enable students to adapt easily to globalisation and the rapidly expanding knowledge.
2. Industrial	Skills that are required beyond the scientific and professional skills and which are necessary in their work place.
3. Humanistic	Helps create a balanced engineer with high ethical and moral values.
4. Practical	Enable students to be directly involved in hands on activities or real-life situations.
5. Professional	Covers the technical competencies required to perform specific engineering tasks.
6. Scientific	Enables students to have a firm foundation in engineering science, predisposing an interest in R&D and innovation.

Participants were asked to map MEEM's six competencies and skills against the 13 programme outcomes and qualitatively determine the level of treatment/importance using a scale of three by assigning (1) for slight (2) for moderate and (3) for substantial treatment/importance. Participants were individually requested to assign the level of treatment/importance so that the senior members may not influence the juniors. Some results of this exercise are shown in Tables 3.0 and 4.0.

Table 3.0 Number of participants who assigned (3) to the respective competencies & skills againsts outcomes

MEEM's Competencies & Skills	Program Outcomes													
	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
1. Global and strategic	6	3	1	2	9	6	4	10	11	6	6	5	5	74
2. Industrial	3	1	5	6	11	11	5	10	7	4	5	9	3	48
3. Humanistic	0	0	0	3	10	0	11	10	8	2	2	0	2	48
4. Practical	9	11	6	3	6	10	0	0	1	1	4	11	6	68
5. Professional	16	11	13	10	4	14	5	2	3	3	8	16	13	85
6. Scientific	17	12	9	5	1	11	0	0	3	8	2	10	7	85
Total	51	38	34	29	41	52	25	32	33	24	27	51	36	

Table 4.0 Competencies & Skills to Outcomes matrix where at least 50% of the participants assigned (1), (2) or (3)

MEEM's Competencies & Skills	Program Outcomes												
	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Global and strategic					3			3	3				
2. Industrial					3	3		3				3	
3. Humanistic					3		3	3			1		
4. Practical	3	3				3				2	2	3	
5. Professional	3	3	3	3		3					2	3	3
6. Scientific	3	3	3			3						3	

The matrix provides a qualitative indication for the relationship between competencies and skills that represents the areas (groups of courses) to the program outcomes. For example, from Table 3.0, participants were of the opinion that MEEM competencies and skills 4, 5 and 6 should be given significant treatment/importance to satisfy outcome number 1, where as MEEM competencies and skills number 1, 2 and 3 to satisfy the outcome number 5. Effort to total up the assigned values across and down does not provide any conclusive relationship. As such Table 4.0 provides a quick solution to the mapping process where when greater than 50% of the participants agreed that the competencies & skills deserve a (3) for a particular outcome then it must warrant some importance. Where a particular outcome was not getting the 50% (giving (3)) support from participants, they were then asked to assign (2), (1) or nothing and again greater than 50% support from the participants was recorded. This is a crude version of decision making and especially useful when time for deliberation is limited. It does not mean that the detail breakdown within the respective competencies & skills would deserve the same treatment/importance. This method would prompt individuals/groups that would later be assigned to develop the learning objectives of the respective area (group of courses) to give greater thought before deciding on the level of treatment/importance of the 'agreed significant' outcomes.

Further brainstorming among the participants identified the different areas (groups of courses) under the respective MEEM's competencies & skills and a further matrix was developed to give a qualitative indication on the treatment/importance of each areas to the programme outcomes. The matrix is shown in Table 5.0, where a similar level of treatment/importance (1), (2) and (3) was also used. This time a further refinement was made as each competency & skill was broken down into several areas. Again, the qualitative values only provide some guidance to the curriculum developer and the final values would depend on the further breakdown of each area. It is interesting to note that as greater detailing is required to be explicit in the learning objectives, the qualitative level of treatment/importance becomes more refined or varied despite under the same area (group of courses).

After having gone through several mapping stages it was concluded that a simpler approach of expanding MEEM's competencies & skills into well defined areas (groups of courses) and mapping them against the outcomes could be taken. This technique is suitable if there exist such a model or the existence of a relatively well defined curriculum is available.

COURSE LEARNING OBJECTIVES AND INDICATORS

Detailing of the each area with learning objectives forces academic staff to think seriously on the treatment or depth of learning required for each learning objective. The indicators as to how and at what level these learning objectives are to be measured are indicated by the methods of assessment adopted for each topic within the area and the hours the students need to be given to attain the specified learning outcomes. Table 6.0 gives an example of a course within an area specifying the treatment/importance with respect to the 13 programme outcomes. This was the last stage of the process where the refinement took place. The final assigned values depend on this stage as shown in Table 6.0.

After having able to detail out an area, the division of the area into several individual courses can be carried out depending on the number of assigned student contact hours. Although individual/group assigned to the specific area may list exhaustively and provide in-depth learning objectives, there exists a limit on the duration of a programme. It is here that the final touch is made bearing in mind that the expected competencies & skills (for the first educational block) are taken care and identify which of the sub-disciplines are to be given the in-depth treatment. It is not an easy decision but one must refer to the programme objectives to confirm the treatment/importance to be given. As such, sub-disciplines that are given equal treatment in the present curriculum may now be reduced to just to cater for the essential knowledge and allow specialization to the 'international level' to take place. It may also mean requiring retraining of some staff or engaging of new staff to undertake teaching within the expanded area.

Indicators in Table 6.0 refer to the evidence to be obtained to show that the students had the necessary level of knowledge, skills and attitude. Reports, examination answer scripts, oral presentation, interviews, observations in class, interpersonal communication and drawings are examples of evidence that could be provided by the educational establishment. It is here that problem-based learning, project-oriented study, instructional study, cooperative learning could be integrated to provide the most appropriate blend of learning mechanisms.

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Table 5.0 Further matrix to show the relationship for areas (groups of courses) to the programme outcomes

Competencies & Skills (Areas of knowledge)		**Program Outcomes**												
1	**Global and Strategic**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
	English					3			3	3				
	Creativity					3			3	3				
	Communications/ Group dynamics					3			3	3				
2	**Industrial**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
	Financial Management	1	2	2	1	3	3	2	3	1	1	2	1	
	Engineers & Society				2	3	2	3	3	2	1	3		
	Economy				1	3	3		3					
3	**Humanistic**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
	Islamic/Asian civilization/ Nationhood					3		3	3					
	Contemporary Issues and Thoughts			1	2	3	2	3	3	2	1	3		
4	**Practical**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
	Survey Camp	3	3	1	1	2	3	1	1			1	3	
	Final Year Project	3	3	2	1	2	3	2	2	1	2	1	3	2
	Industrial Training,	3	3	2	1	2	3	2	2	1	2	1	3	
	Engineering Drawing and Drafting	3	3	1		1	3		2			1	3	
5	**Professional**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
	Structural Design	3	3	3	3	1	3	1			2	2	3	3
	Geotechnical Design	3	3	3	3	1	3	1			2	2	3	3
	Civil Engineering Design and Detailing	3	3	3	3	2	3	2	1	2	2	2	3	3
	Water and Wastewater	3	3	3	3	1	3	1		1	2	2	3	3
	Geomatics & GIS	3	3	3	3		3	2	1		2	2	3	3
	Project Management	3	3	3	3	2	3	2	2		2	2	3	3
	Quantity Measurements	3	3	3	3	1	3	1	1		2	2	3	3
	Highway & Traffic Engineering	3	3	3	3	2	3	2	2	1	2	2	3	3
6	**Scientific**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
	Engineering Maths & Computer Programming.	3	3	3			3		1		1	2	3	2
	Geo-mechanics	3	3	3			3		1		1	2	3	2
	Fluid Mechanics, Hydraulics & Thermodynamics	3	3	3			3		1		1	2	3	2
	Engineering Mechanics & Structural Analysis	3	3	3			3		1		1	2	3	2
	Environmental Sciences	3	3	3	2		3	1	2	1	1	2	3	2
	Engineering Materials, Strength of Materials	3	3	3	2		3		2	1	1	2	3	2
	Electronics & Electrical Technology	3	3	3			3				1	2	3	2

Note: Financial management, economy, quantity measurements, project management are reclassified as Construction to include construction technology

Table 6.0 Course learning objectives and indicators mapped against programme outcomes

Course: CIVIL ENGINEERING DESIGN PROJECT

This is a capstone design course where 4 groups of students (5 in a group) need to apply the fundamental knowledge and the professional competency that they had obtained in their earlier semesters to undertake a civil engineering project design. Students are expected to work in teams to produce a project brief and a detailed project document up to costing.

	Learning Objectives	Existing Course Ref	1	2	3	4	5	6	7	8	9	10	11	12	13	Indicators	Students Hours
1	**Seminars**	KAW 3927 Synopsis					1		2	1	3	1	3		3	(7) Seminars Summary Report	14
	Summarise not more than one page on the seminars attended in team/individual															Group dynamics/individual will be observed	
2	**Civil Engineering Tools**	KAW 3927 Synopsis					1				1	1	3	3	3	(3) CE Tools Assignment Report	15
	Describe the use of contemporary civil engineering (CE) tools after listening to the presentations and having used the tools															Group dynamics will be observed	
3	**Managing Design Project**	KAW 3927 Synopsis		2			3	1	2	3	2	2	1	2	1	Project Plan	5
																Weekly Minutes	28
	Manage the project assigned to the team which includes planning, implementation, and conduct of meetings															Group dynamics will be observed	
4	**Project Brief**	KAW 3927 Synopsis	1	3	2	2	3	3		1	1	3	3	3	3	Project Brief Report	18
	Develop project methodology (how, what and when) and conceptual design (to include advanced level design), and undertake role play of the relevant stakeholders															Group dynamics will be observed	

	Analyse collected documents (eg. codes, design reports, literatures) to provide the framework for a project brief																
	Prepare a project brief in team taking into consideration the client needs																
5	**Proposal Presentation**	KAW 3927 Synopsis					3	1		3		1	1			Oral Presentation	6
	Present and defend the proposal (project brief) in team															Group dynamics will be observed	
6	**Analysis, Design, Drawing & Detailing**	KAW 3927 Synopsis	3	3	3	3	3	3		1	1	3	3	3	3	Final Project Report	160
	Collect relevant data and information, and conduct analyses of the agreed structural/infrastructural works															Group dynamics will be observed	
	Design the structural/infrastructural works																
	Produce drawing and detailing, and costing																
	Prepare a project report in a team																
7	**Final Presentation**						3	1		3		1	1			Oral Presentation	6
	Present and defend the final report															Group dynamics will be observed	
	Total/no of relevant learning objectives within an outcome		2	3	2	3	2	2	2	2	2	2	2	3	3		252
	EARLIER PROPOSED OVERALL RATING		3	3	3	3	2	3	2	1	2	2	2	3	3	2.50 - 3.00 = 3 1.50 - 2.49 = 2	6 credits
	FINAL REVISED OVERALL RATING		2	3	2	3	3	2	2	2	2	2	2	3	3		

CONCLUSIONS

In developing an OBE curriculum consideration of programme objectives and outcomes, and course objectives and outcomes as well as performance indicators should be taken on board from the beginning. Every stated objective and outcomes must and can be assessed and evaluated. It is nor longer processed driven or lecturer centered, but is centered around the needs of the students and the stakeholders. Every learning outcome is intentional and not by inference. All learning outcomes must be assessed using suitable performance indicators. Programme objectives address the graduates' attainment within 3-5 years after their graduation. Programme outcomes, which consist of abilities to be attained by students before they graduate, are formulated based on the programme objectives and encompass the outcome requirement by accreditation bodies. Programme outcomes are expected to address Knowledge, Skills and Attitudes to be attained by students. Course outcomes must satisfy the stated programme outcomes and there is no need for any course to address all programme outcomes. Teaching/ Learning method may have to be integrated to include more of problem-based learning to complement the traditional instructional learning method.

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