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Coupled Mastery-Humility: a Converging model for the Training of Engineers

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ABSTRACT
A coupled and convergent mastery-humility is developed as a measurement tool for assessing outcomes beyond competent and ethical. The level of competency reaching mastery and ethical value attaining humility. A mixed-method sequential exploratory design approach was adopted for the study. The first stage's inquiry was guided by the Straussian Grounded theory, and the second stage by using confirmatory Factor Analysis (CFA) and structural equation modelling (SEM). Six constructs and 24 survey items developed were then subjected to the questionnaires survey. The results indicate the convergence of mastery and humility. The fit indices obtained are: RMSEA = 0.068 < 0.08, CFI = 0.963> 0.95 and TLI = 0.951 > 0.90. Thus, the theoretical proposition is verified because it fitted the data. The use of this model as a measurement tool for the cognitive and affective domains are proposed.

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I. INTRODUCTION

The education of an engineer consists of formal and informal training. The former comprises the primary, secondary and tertiary forms of education. The schooling period's duration is the same for many countries, namely 12 years before entering the University for a four-year Degree Programmes in any engineering disciplines [1]. The focus of his/her studies in the primary and secondary stages should be preferably in mathematics and science because engineering by definition is simply the utilisation of forces for the public good [2] , and forces are represented by mathematical, scientific and/or physical models (Isaac Newton, 1643-1727).

Engineering training differs from that of the scientists' since science is an inquiry, the essence of engineering designs. The former extends the insight of one's knowledge and the latter designs and makes physical realities of the thought process results. Engineers' tasks are to build/make things that are not there yet, but the scientists carry out studies on their status quo to better comprehend the existing resources [3].

The engineering curriculum is designed to follow a general path of shifting the emphasis from engineering science and principles from the beginning towards more integrated studies at the end [1]. The learning domains are cognitive, psychomotor and affective. It covers basic and advanced mathematics and science, basic and advanced engineering and industrial practice. The graduates are being prepared to solve 'real-world' problems in the workplace

II. STATEMENT OF PROBLEM

The outcomes of all accredited engineering programs are normally competent and ethical. The former can be measured but not ethical. In classes students are trained to answer questions. In the 'real-world' they need to assess and define the situations, and then solve the 'right' problem. They need to achieve both technical and moral competencies. So there is a need to develop such combination at the undergraduate level. This paper describes the development of a model that can be used as a measurement tool for these variables.

III. ENGINEERING COMPETENCY AND PROFESSIONALISM

Competent person can complete any tasks satisfactorily to an acceptable quality or standard, of which the accomplishment requires the necessary level of comprehension, judgment, skill, and level-headedness[4]. Professional competence is acquired through the correct mix of formal and informal education, on-the-job training and relevant experience.

An engineer is competent when he can appreciate knowledge in transforming into the physical world. Competence is the ability to execute a task to a sufficient standard. To achieve competency requires the right level of knowledge, skill and understanding, and a certain level of professionalism. It is developed by a

combination of informal and formal learning, training and participation, generally known as initial professional development. However, these elements are in unstructured forms.

Another definition is that one who can perform with minimum supervision is competent. He/she should be able to perform what he is being trained for, and he should be able to demonstrate the learning outcomes. In the professional assessment guidelines document, competence is defined as executing a task adequately. To achieve competency, it requires the right level of knowledge, skill and understanding, and a certain level of professionalism. It is guided by the IEM Competency Model, which demonstrates the foundation of knowledge and understanding of engineering fundamentals, application abilities, leadership and management skills, interpersonal skills and personal commitment to the profession that must be demonstrated to practice professionally[4].

IV. MASTERY-HUMILITY MODEL: CONVERGENT

This paper addresses the outcomes of engineers' formal training, namely the balanced form of the attributes pertaining to the two learning domains: cognitive and affective. The model is developed with a sustainability approach in mind holistically combining competency and ethical. The level of competency reaching mastery and ethical value attaining humility.

Mastery Attainments

Generally, in Engineering, one is a novice when he is new to his job or knows little. As an engineer in training, supervising engineers assessed his ability to apply what he has learned as students and accept becoming a Professional Engineer. He becomes competent when he can perform to basic standards based on the Code of Practice and becomes 'experienced' when he can cope with any challenges demanding his skills. He achieves mastery when he can invent new and better ways to do a job. In other words, he can optimise by being efficient in his design.

Mastery is typically equated with having Professional qualification, which is obtainable after spending many years working. The other type of mastery is at the undergraduate level indicated by the student's outstanding scholarly achievement, and this number is minimal. Thus, a mastery that is adopted here is the assessment of any student's potential who shows the indication that he can shoulder the responsibility of a vicegerent. In other words, can he, as an engineer utilising the earth's resources sustainably in his design. The available setting is in the Capstone Design Class/ Integrated Design Project (IDP).

There is a distinct difference between mastery and competency though most agree that one who has the mastery of the field by default he is supposed to be competent. Mastery as higher than competency. It seems that individuals can reach that level after many years in practice, some equated mastery as Master-Craftsman. The individual has reached a certain level in a particular area. He also knows other things too apart from that area, but he has in-depth knowledge of that particular area. Being a master of something means that there is realisation that there are still a lot more to learn because people who say they know everything they are not a master of it actually because they think they know everything. In this paper, an indicator of mastery needed to be established as an instrument to gauge the potential of the students in reaching that level in the future as he/she practices. In order to see the potential of achieving mastery, it is necessary to observe an individual student's ability in the class.

Humility

Humility is defined as compassion for others, willingness to share credits for accomplishment and usually accompanied by higher levels of humaneness, tenderness, honour and value. Humility differs from low self-esteem and not the opposite of confidence. It is not also wallowing in self-pity. Humility is an indicator or sign of strength, virtue, and incredibly empowering. It is a reflection of spiritual, mental and emotional maturity.

Humility is a positive outlook of oneself [5], having integrity and dignity. It was defined as : the ability to respect the truth from wherever it comes from, knowing his/her proper place and position in the society, and to regard highly contribution of others to the society, de-emphasising one's equally significant role[5].

As mentioned by Emmons [6], being modest is really about one's true and genuine self-evaluation. The perception of humility as one who has been experiencing frequent failure and therefore has low self-worth is incorrect (Roberts, 1983). In actual fact, they are the high achievers with praise-worthy accomplishments and who have mastered his field/area but remain humble.

In engineers' education, the instilling of confidence level for the graduates will possibly bring about 'arrogant' as the outcome. To counter this possibility, it is the humility traits than can achieve balance and level-headedness. Humility will be like a moral compass to lead them to achieve moral competence.

V. CURRICULUM

The engineering curriculum is normally completed after four years of undergraduate study after 12-13 years of Secondary School education [1]. The basic mathematics and sciences are taught in the first year dealing with the fundamentals and physics and chemistry principles, especially the former forms the significant components in the study. The forces of nature are expressed in mathematical forms. The derivation from first principles is carried out to arrive at expressions depicting the relationships or laws. The mathematical, physical, laboratory and computer models are tools for design purpose in the final year integrated design project.

Integrated Design Project Course/Capstone Design Project normally taught in the final two years is an indicator of the disciplines' competency [1]. In this study, the mastery indicator is accomplished in the Integrated Design Project (IDP) for several reasons: the training to deal with 'real world' problems, working as a team member, and using a sustainability design approach for an efficient design. The course outcomes for this course are as follows (Table 1):

Table 1. Course Outcomes (COs): Integrated Design Project (IDP)

Course Outcomes (COs)	Statements
CO1	Defining and formulating problem solving to complex design problem
CO2	Utilising defensible manual and code of practices with available resources maintaining a close attention to the preservation of the environment and issues related to rules, legislation, safety and health and other societal obligations
CO3	Justify with informed reasoning and consideration on consequent responsibilities to the society
CO4	Accommodate the concept of sustainability in the project design
CO5	Practise effective engineering management in the project design
CO6	Demonstrating skills of leadership and as a co-worker in a team, capable of delivering collaborative results in the forms of design and product outcomes subject to the rigor of analysis and evaluation procedures

VI. RESEARCH METHODOLOGY

The research approach adopted is the sequential exploratory design, combining qualitative and quantitative research methods, 'QUAL quant' approach. Data were collected by semi-structured interviews using the grounded theory approach, questionnaires survey and documents analysis. More weight is attached to the semi-structured interviews' data, the core qualitative component until the saturation point.

The method of enquiry for the emergent of proposition made use of the Straussian grounded theory approach. This method allows a more linear approach to the build-up of the emergent theory using lots of comparison, recursive and memoing techniques. Confirmatory Factor Analysis (CFA) was used to test how well the measured variables represent the constructs. The structural equation model (SEM) analysed the structural relationship between the measured variables and latent constructs.

The major study involved a case study of two universities (X and Y) with a predominantly Malay-Muslim population. A pilot study with 30 undergraduate students was carried out to try out the questionnaires on the mastery-humility model developed based on the pilot semi-structured interviews. The Cronbach's coefficient α was 0.71 for the whole scale. The questions then were modified with the addition of 2 more survey items to make it 24 after the completion of the semi-structured interviews of 32 academics and upon achieving the theoretical saturation. The questionnaires survey involved the third and fourth year students since they have already completed most of the enabling and culminating courses.

VII. RESULTS AND DISCUSSION

Qualitative Study

In the pilot study, the findings indicate the following:

Competency Traits

All informants agreed that the current curriculum could achieve competency. It is achievable and measurable; it is aligned with the present outcomes. The learning outcomes matched that of the attained outcomes. There are two levels of measurement of competency, one at the entry point of the market or the convocation, the other at 3 - 5 years after graduation, said Informant A1. Being employed means accepting the graduates' competency and holding a senior post and leading a project after 3 to 5 years means competent at the post-graduation period.

Measurement of humility

The other theme that has been highlighted is humility. All Informants mention humility as one with humbleness. However, because the humility dimension is not included in the rubric of outcomes, it is not measured. Even the ethics element is missing in the measurement, although the ethical dimension's outcome is desirable. So, although all three agreed to have this quality in the attributes of their graduates in the present circumstances but are unable to suggest any measuring tools. The only instance that academics deal with it is a component in the Engineer in Society Course. It is supposed to be imbedded in other subjects but it is left to the prerogative of the lecturers. One informant suggested that anyone can have humility but with or without any religious belief.

The difficulty in the assessment of humility concurred with those mentioned in the literature [5,,8,9]. The study of humility is also hampered by the absence of instrumentation tools [10]). This is precisely the reason for a quantitative method like Structural Equation Method (SEM) is employed for the purpose of determining this latent variable,

The piloted interview was followed by the major semi-structured interviews with selected universities' senior academics under study. This exercise generated 30 transcripts which were then systematically analysed for open, axial and selective codes using NVivo. It was then possible to have six constructs (mastery, competence, humility, *ubudiyyah*, deliver and converge) for the confirmatory factor analysis governed by the emergent theory. The survey items resulted were 24 in numbers, with a part of it shown in the Table 1 below for the sub-scales mastery and humility.

Table 2. Survey items of mastery and humility
(Likert scale scores: 1-5)

	Mastery Attainments
5.	I think to design efficiently, the concept of using more from less is possible.
6.	Using materials that will last longer I believe, helps in sustainability design
7.	My role as a Khalifah is to use the resources sustainably for the good of humankind.
8.	I always think that if possible, in design any resources can be used over and over again.
	Factor: Humility and Truthcentricity
13.	I do not copy from another student during a test or quiz.
14.	I think there is always someone better than I am
15.	I let somebody ahead of me in line when I see they are in a hurry
16.	When someone says the truth, I accept it even though he is not someone friendly.

Adapted from EAC (2020)

Quantitative study

The questionnaires developed were then distributed in the present study by Google forms administered questionnaire to the two institutions receiving 507 respondents, made up of 163 students from University X and

344 from University Y. The convenience sampling exercise was carried out for a period of three months (July, August and September, 2020).

By gender distribution; there were 259 male and 248 female students who responded to the survey. The age of 93.9% of the respondents varied from 17 – 25. The respondents comprised 248, 157, 52, 50 Civil, Mechanical, Electrical and Electronics students. There were 66.7 % (338) of fourth-year students; thus, they would have taken most enabling courses and presently took culminating courses.

The results were then analysed. For calibration of the SEM, a pooled Confirmatory Factor Analysis (CFA) was obtained. (Figure 1.)

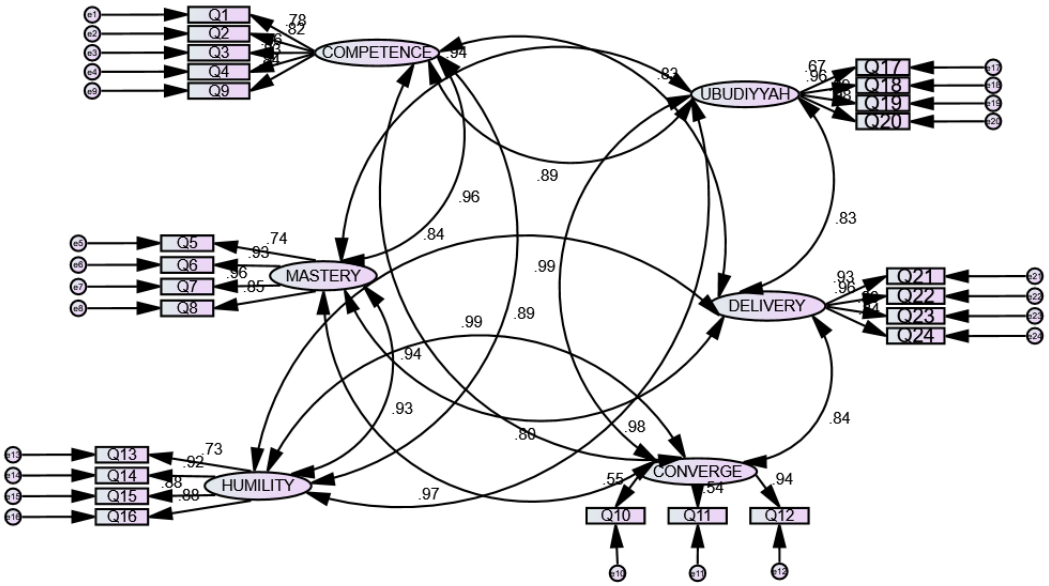

Fig.1. Pooled Confirmatory Factor Analysis (CFA)

For internal reliability, the Cronbach's Coefficient, α for the six constructs, ranged from 0.72 to 0.94. The composite reliability level (C.R.) ranged from 0.73 to 0.95. For validity analyses, the convergent validity's average variance extracted (AVE) for every construct was 0.5 to 0.8 and the discriminant validity's Heterotrait-Monotrait ratio (HTMT) was 0.85. The Confirmatory Factor Analysis (CFA) meets the criteria for the goodness of fit and the construct validity has the following fit indices:

Table 3. Fit Indices (Pooled CFA)

Test	X^2/df	RMSEA	CFI	IFI	TLI	PDF	Helter's Critical N
Value	<4	≤.08	≥.95	≥.90	≥.90	≤1	≥75
Pooled Model	3.924	.076	.952	.952	.944	.804	159(01)

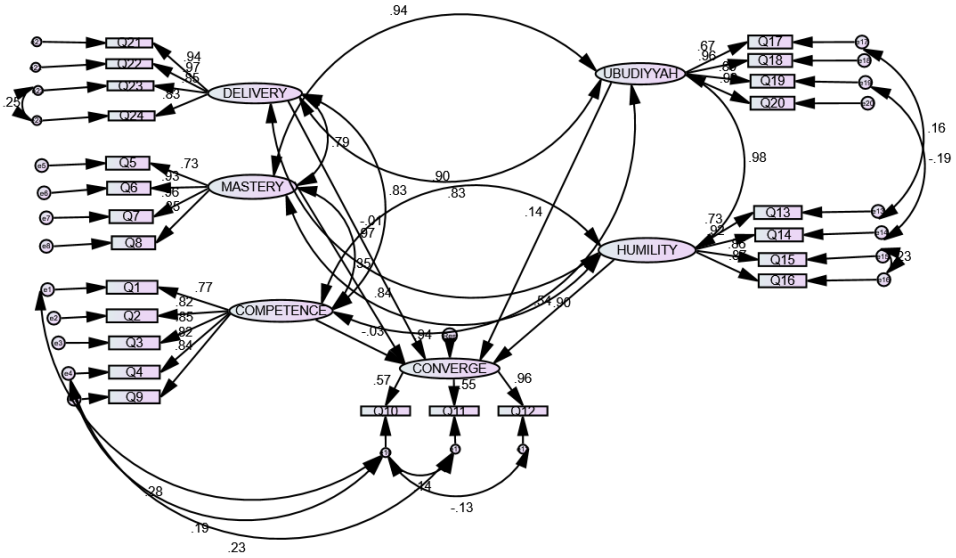

Figure 2. Causal/Effect SEM modelling

Table 4. Fit Indices (Causal/Effect Modelling)

Test	X^2/df	RMSEA	CFI	IFI	TLI	PDF
Value	<4	≤.08	≥.95	≥.90	≥.90	≥.05
Causal Modelling	3.358	.068	.963	.963	.951	.720

Following the calibration, the causal/effect modelling was carried out and the results are as shown in Figure 2. The fitness indices (Table 4) were improved after modifications were done for the following with Modification Indices (MI) more than 15.0:
e1 – e10, e4 – e10, e4 – e11, e10 – e11, e13 – e17, e14 – e19, e15 – e16, and e23 – e24
Chin [11] has suggested in order to be meaningful, standardised regression weights should be more than 0.30. Similarly, standardised factor loadings which range from "0.30 to 0.39, are considered significant, loadings ranging from 0.40 to 0.49 are considered more important, and loadings or greater are considered very significant" [12].

Table 5. Standardised Regression Weights (Causal/Effect Modelling)

Variable		Variable	Estimate
CONVERGE	←	MASTERY	.349
CONVERGE	←	HUMILITY	.545
CONVERGE	←	COMPETENCE	-.031
CONVERGE	←	DELIVERY	-.011
CONVERGE	←	*UBUDIYYAH*	.144

As can be observed from Figure 1 the standardised regression weights for competence → converge = -0.31, delivery→ converge = - 0.11 and *ubudiyyah* → converge = 0.144. So, they are deleted for the final convergent mastery-humility model. Loadings for mastery → converge and humility → converge are .345 (significant) and .545 (very significant), respectively. Thus, direct loadings from mastery and humility (exogenous) on convergence (endogenous) confirmed the converging phenomenon's theoretical propositions.
The use of this model is useful at the beginning of the semester and the end (entry and exit) for the evaluation of students. As a comparison, paired t-test can be used for the sub-scale humility or mastery, but to assess their outcomes, the 24 items in the questionnaires need to be answered and the feedback of them meeting the criteria of fit indices noted. The model and the survey items should be occasionally be improved for better measurement

of those latent parameters of mastery and humility. Competency could be measured conventionally, but mastery, where sustainability design's efficiency is achieved, is done by responding to the pertinent survey items.

VIII. CONCLUSION

The outcomes of engineers' training are competent and ethical. The former is quite accurately assessed but not the latter. Being ethical is entirely subjective, and there is no existing measurement tool in the rubrics. It was meant to be imbedded in all subjects but seemingly unsatisfactorily implemented. It falls under the affective domains, whereas competency the cognitive. The model that is developed here is an attempt to have an instrument for evaluating the coupled mastery-humility. As is discussed above, humility is admirable when someone has mastered or achieved something and he/she has every reason to be proud of but remains humble. Humility is an accurate self-assessment, realising one's strength and weaknesses. He/she is willing to accept the truth from wherever it comes. Thus, it can be concluded that a working model of measuring the latent variables of humility and mastery, as shown above, not only meeting the need for competency and ethical but have gone beyond. It is envisaged that the coupled and the convergent mastery-humility model will make an engineer a wholesome member of society readied to solve 'real-world' problems.

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