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AXIOMATIC DESIGN MODEL TO ASSESS INFLUENCES AFFECTING PEDAGOGIC-LEARNING IN THE COURSES ENGINEERING MATERIALS I AND FLUID MECHANICS I (PART 1)

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ABSTRACT

This paper explores to set an axiomatic design model in the Assessment of Influences Affecting Pedagogic-Learning in order to succeed in finding core factors affecting student's performance for the courses Engineering Materials I (CE 221) and Fluid Mechanics I (CE 211-F). These subjects are the building blocks of engineering knowledge, thus require that the student should grasp the knowledge before he/she moves to the next level. The survey aims to understand what student influential factor best relate to teacher goals. The questions asked to get the perception of what influences students' about pedagogic-learning on the two subjects were taken from a inventory of teaching goals by Angelo and Cross (1993). On the course Engineering Materials I (CE 221), there are 92 second-year students from Mineral Processing, Mining and Civil Engineering. On the other hand, there are 42 second-year students from Civil Engineering for the course Engineering Fluid Mechanics I (CE 211-F). The study uses the axiomatic design (AD) principles in finding success on the assessment of the influential factors that affects student pedagogic-learning. The study found that by using AD, the analysis of the assessment is simplified and the factors that influence the students in each subject are best identified. The result of the assessment helps the author identifying the gap of teaching and learning and to find ways to bridge that gap using a new framework to address the challenges of culture-rich and educational-poor factors of influence in pedagogic learning. This document is composed by two parts.

Keywords: Pedagogic-learning, assessment, framework, influences, model.

1 INTRODUCTION

Papua New Guinea (PNG) has an abundance of natural resources, with mineral deposits like copper, gold and oil accounting about 72% of export earnings or nearly two-thirds of PNG's export revenues. PNG has embraced an economy boom in the last ten years particularly in the sector of resources, but the human development (2013) is only 0.466% of average Human Development index in the Asia Pacific region as of 2013, according to the Human Development Report of the United Nations, while the international average Human Development index was 0.694% and the Asia Pacific region recorded 0.68%. Former Lae MP Bart Philemon (Human Development, 2013) pointed out that 2-3 million (the 7-21-years old, as per the 2011-2012 National Population Census report) Papua New Guineans, out of a population of more than seven million, are illiterate and describe the country as an island of gold floating on oil, which means "our country is richly blessed with many natural resources that is the envy of many other countries". But despite these blessings, PNG is ranked 153 out of 187 countries and noted as the 34th poorest ranking nation in the world in terms of human development as measured by United Nations. The Asian Development Bank (2003) forecasted that neither economic nor social change is likely to occur without a literate and healthy population, education is a major determinant of development everywhere in Asia and the Pacific.

For engineering courses, failure rates are as high as 35% (Karim, 2011) because students have real problems in understanding some fundamental concepts and principles if they are abstract in nature. The author's experience in teaching reveals students' difficulty in the courses of Engineering Materials I (CE 221) and Fluid Mechanics I (CE 211-F). The CE 211-F is combined with Engineering Solid Mechanics, making it a 8-hour coursework. With a large number of students in a class setting for CE 221, it is likely that those circumstances may influence the students' performance.

Ravinder (2011) found that today's educational struggle in PNG is a struggle for pedagogy, more specifically, PNG pedagogy that is responsive to the PNG condition today. Pedagogy is based on a premise that the purpose of education is to transmit knowledge and skills (Knowles, 1980). As defined by Wikipedia, Knowledge (2013) is a familiarity with someone or something, which can include facts, information, descriptions, or skills acquired through experience or education and can refer to either theoretical or practical understanding of a subject. It can be implicit (as with practical skills or expertise) or explicit (as with the theoretical understanding of a subject); it can be more or less formal or systematic. Malcolm Knowles (1980), who popularized the pedagogical concept in the United States in the 1970's, define pedagogy as the art and science of teaching children, as derived from the Greek words *paid*, meaning "child" and *agogus* meaning "leader of". This concept is not limited to children but is adaptive to adult learners too. In his article Pedagogy & Technology, Webb (2014) defines pedagogy as teaching for learning through activities that impart knowledge, which are illustrated as:

Technology -> activities -> tasks -> (products + experiences -> learning) -> outcomes
Teaching = scaffolding learning activities + mediation of learning experiences
Learning = (activities ->) experiences + programmed knowledge + questioning insight

Learning outcomes must be measured so that whatever deficiency in learning can be alleviated by the teaching strategies on the next time the same subject is thought. Teacher matters (2014) says that many factors contribute to the student's academic performance, including individual characteristics and family and neighborhood experiences. But research suggests that, among the school-related factors, teachers matter the most. When it comes to student performance, the teacher is estimated to have two to three times the impact of any other school factor, including services, facilities, and even leadership. Rachal (1983) stressed that the lecturer direct approach, or the pedagogical approach, would still require the lecturer to follow a free exchange of ideas and to allow students to pursue personal interests (through papers, projects, or presentations) as long as they go along with the course objectives. The lecturer must also provide leadership and take primary responsibility for evaluation to determine that the expected result is obtained.

Teaching is a complex activity that is strongly affected by external decisions about curriculum and assessment. The teacher plays a crucial role in the implementation of curriculum and assessment, as well as in the student achievement. Research has identified some teaching effectiveness factors, such as teacher expectations of their students, teacher knowledge of the subject, and other learning approaches which contribute to the feedback associated with formative assessment strategies. The author believes that the use of evaluation helps to reduce high failure rates, as they are costly to all stakeholders since the throughput of the University is reduced. This increases the cost of training graduates, as well as reducing admission opportunities for high school students seeking a University education. For a country like Papua New Guinea, where there is only one technological university, as well as for the rest of the Pacific Islands, with an intake of fifty students a year per discipline, low pass rates impose a huge cost in terms of low number of students graduating and reduced intake of potential students due to the shortage of space caused by the low throughput of the university.

It is in this premise that the study is conducted in order to determine the student personal philosophies that influence their learning as directed by the teacher (pedagogic) in the courses Engineering Materials I (CE 221) and Engineering Fluid Mechanics I (CE 211-F).

1.1 TEACHING STRATEGIES AND ASSESSMENT IN THE COURSES CE 221 & CE 211-F

The teaching strategies that the researcher used in the courses are lectures, tutorials, and experiments. The outlying concepts and principles in the courses are given in lectures and are reinforced during tutorial sessions. The hands-on of some outlying concepts and principles are conducted by laboratory experiments. Because of a large group of students attending the experiments and the limited number of laboratorial setups, the laboratory experiments are just exhibited by the technical personnel that support the courses. The assessments used to measure student's achievements are: assignments (A), quizzes (Q), laboratory experiment reports (L), and written final examination as shown in Table 2.

Table 1. Arrangement of the **teaching strategies for CE 221 & CE 211-F**

	Method	Contact hours		number of AQL		Grading % weight	
		CE 221	CE 211-F	CE 221	CE 211-F	CE 221	CE 211-F
Teaching Strategies	Lectures	1	3				
	Tutorials	1	1				
	Experiments	1					
Assessment	Assignments, A			6	3	12	15
	Quizzes, Q			6	3	16	15
	Lab Reports, L			3	3	8	5
	Attendance	Every meeting		Every meeting		4	5
	Final Examination	At the end of each semester		At the end of each semester		60	50

Student consultation is already incorporated in the tutorial sessions, in which the reinforcement on the contents is made to increase student's content grasp of the subject matter and is believed to help them increasing their internal marks or continuous assessments.

1.2 SAMPLE USED IN THE COURSES CE 221 & CE 211-F

There is a total number of 118 second-year students from Mineral Processing (BEMP-2), Mining (BEMN-2) and Civil Engineering (BECV-2) enrolled in the first semester of calendar year 2013 for the course Engineering Materials I (CE 221), and 47 second-year students from Civil Engineering for the course Engineering Fluid Mechanics I (CE 211-F) who responded a questionnaire. The questionnaire was given to the students on a reward scheme of additional two (2) marks added to their internal marks or continuous assessments in order to get a majority of responses and encourage them to fill up the questionnaire with diligence. However, only 92 complete turnouts of 107 returned questionnaires were considered in this study, out of 118 distributed questionnaires for CE 221 and 47 for CE 211-F with 44 returned questionnaires and 42 complete turnouts. Sampling criteria below as applied results to an appropriate sampling for both courses on study.

The sampling criterion is based on the Slovin's formula:

$$n = \frac{N}{1+Ne^2} \quad (1)$$

where:

n = sample size
N = population size
e = margin of error

1.3 SURVEY TOOLS USED IN THE ASSESSMENT OF COURSES CE 221 & CE 211-F

The survey tools used in the analysis of influences are items of questions from the teaching goals inventory list of Angelo and Cross (1993), which the author believes that embodies the desired teaching goals in the learners' point of view. There are fifty closed-type questions to find what best influences the student (according to a five-point Likert scale) with the following descriptors:
(1) *Not applicable*, an influence that student never want to have;
(2) *Unimportant*, an influence that student rarely want to have;
(3) *Important*, an influence that student sometimes want to have;
(4) *Very Important*, an influence that student often want to have;
(5) *Essential*, an influence that student always/nearly want to have.

Table 2. Set of Influences Questions in the Survey of **Student's Perception**

Item	Description of Influence
1	Influences that develop ability to apply principles and generalizations already learned to new problems and situations.
2	Influences that develop analytical skills.
3	Influences that develop problem-solving skills.
4	Influences that develop ability to draw reasonable inferences from observations.
5	Influences that develop ability to synthesize and Integrate information and ideas.
6	Influences that develop ability to think holistically: to see the whole as well as the parts.
7	Influences to develop ability to think creatively.
8	Influences that develop ability to distinguish between fact and opinion.
9	Influences that improve skill at paying attention.
10	Influences that develop ability to concentrate.
11	Influences that help improve memory skills.
12	Influences that help improve listening skills.
13	Influences that help improve speaking skills.
14	Influences that help improve reading skills.
15	Influences that help improve writing skills.
16	Influences that help develop appropriate study skills, strategies, and habits.
17	Influences that help study skills, strategies, and improve mathematical skills.
18	Influences that help learn terms and facts of this course.
19	Influences that help learn concepts and theories in this course.
20	Influences that develop skill in using materials, tools, and/or technology central to this course.
21	Influences that help learn to understand perspectives and values of this course.
22	Influences that help learn techniques and methods used to gain new knowledge in this course.
23	Influences that help learn to evaluate methods and materials in this course.
24	Influences that help learn to appreciate important contributions to this course.
25	Influences that help develop openness to new ideas.
26	Influences that help develop an informed concern about contemporary social issues.
27	Influences that help develop a commitment to exercise the rights and responsibilities of citizenship.
28	Influences that help develop a lifelong love of learning.
29	Influences that develop aesthetic appreciations.
30	Influences that develop an informed historical perspective.
31	Influences that develop an informed understanding of the role of science and technology.
32	Influences that develop an informed appreciation of other cultures.
33	Influences that develop capacity to make informed ethical choices.
34	Influences that develop ability to work productively with others.
35	Influences that develop management skills.
36	Influences that develop leadership skills.
37	Influences that develop a commitment to accurate work.
38	Influences that improve ability to follow directions, instructions, and plans.
39	Influences that improve ability to organize and use time effectively.
40	Influences that develop a commitment to personal achievement.
41	Influences that develop ability to perform skillfully.
42	Influences that cultivate a sense of responsibility for one's own behavior.
43	Influences that improve self-esteem/self-confidence.
44	Influences that develop a commitment to one's own values.
45	Influences that develop respect for others.
46	Influences that cultivate emotional health and well-being.
47	Influences that cultivate physical health and well-being.
48	Influences that cultivate an active commitment to honesty.
49	Influences that develop capacity to think for oneself.
50	Influences that develop capacity to make wise decisions.

1.3 DEMOGRAPHIC AND SOCIAL PROFILE

The demographic and social profile where not included in the analysis for factoring and regression as the author consider it irrelevant because lectures and other activities in the classroom are conducted for both genders or wherever they come from and their other preferences. These information are equally useful to help the researcher established an information base which may have interest from whatever the result of the assessment of influences affecting pedagogic learning earlier presented. The data is presented in table 3.

Table 3. Demographic and Social Profile for CE 221 & **CE 211-F Respondents**

Description	CE 221		CE 211-F	
	f	%	f	%
1. Self-motivation to study the course				
Lecturer's instruction	1	2.38	6	6.52
Grade	6	14.29	4	4.35
Develop higher order thinking skills	4	9.52	23	25.00
Prepare for job/careers	26	61.9	50	54.35
Foster development and personal growth	2	4.76	3	3.26
Develop basic learning skills	3	7.15	6	6.52
2.Method of submission course undertaking				
Student server	7	16.67	27	30.43
Hard copy	33	78.57	55	59.78
Soft copy (via email)	11	4.76	9	9.78
3. Strategies and Assessment				
Lecture	11	26.19	28	30.43
Laboratory/Test	15	35.71	19	20.65
Assignment	11	26.19	35	38.04
Quiz	5	16.67	10	10.87
4. Information Collection				
Internet	32	76.19	67	72.83
Books at the library	3	7.15	2	2.17
Books own	2	4.76	3	3.26
Lecture notes	5	11.90	20	21.74
5.Peer Impact				
Yes	30	71.43	44	47.83
No	12	28.57	48	52.17
6. Gender				
Male	39	92.86	75	81.52
Female	3	7.15	17	18.48
7. Living in Dormitories				
Yes	41	97.62	83	90.22
No	1	2.38	9	9.78
8. Lae, Morobe resident				
Yes	0	0	2	2.17
No	42	100	90	97.83
9. Scholar				
Yes	37	88.10	71	77.17
No	5	11.90	21	22.83
10. Course Selection				
Yes	25	59.52	51	55.43
No	17	40.48	41	44.57
11. Finances				
Yes	21	50	49	53.26
No	21	50	43	46.74
12. Information Gathering				
Free will to use search engine	36	85.71	73	79.35
Directed to a link	6	14.29	19	20.65
13. Background in Mathematics				
Good	37	88.10	NA	NA
Not	5	11.90	NA	NA
14. Critical thinking				
Exercise by self	38	90.48	NA	NA
Exercise as directed	4	9.52	NA	NA
15. Understanding in real life				
Yes	41	97.62	NA	NA
No	1	2.38	NA	NA

where f is the frequency of the responses.

The students are as diverse as the country's population with more than 800 languages and a culture that is many-sided and complex. It is estimated that more than 7000 different cultural groups exist in Papua New Guinea, and most groups have their own language. Because of this diversity, which is a matter of pride, many different styles of cultural expression have emerged; each group has created its own expressive forms in art, dance, weaponry, costumes, singing, music, architecture and much more. In addition, the presence of international students from other Pacific Island countries like the Solomon Islands makes it even more diverse. The Papua New Guinea University of Technology is the only technological university in the country and in the Pacific (except Australia and New Zealand).

2 AXIOMATIC DESIGN MODEL (ADM)

Axiomatic design (2014) is defined as a systems design methodology using matrix methods to systematically analyze the transformation of customer needs into functional requirements, design parameters, and process variables. Nam Suh (2001) defines Axiomatic Design, as the creation of synthesized solutions in the form of products, processes or systems that satisfy perceived needs through a mapping between Customers Needs (CNs), Functional Requirements (FRs) Design Parameters (DPs), and Process Variables (PVs) that consists on the mapping of "what we want to achieve" and "how we want to achieve it", as shown in figure 1.

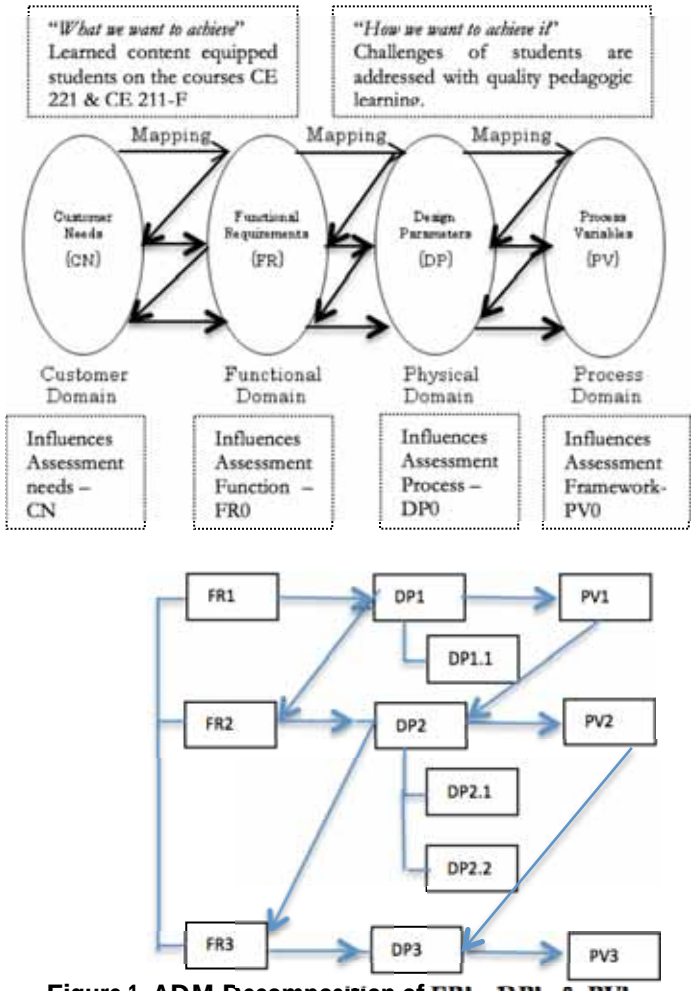

Figure 1. ADM Decomposition of FR's, DP's & PV's

The interpretation of what is the Customer Domain-Customer Needs (CNs), Functional Domain-Functional Requirements (FRs), Physical Domain-Design Parameters

(DPs), and Process Domain-Process Variables (PV)s is given in table 4.

Table 4. **Definition of ADM Parameters**

What we want to achieve?	
CN	Assess effectively CE 221 & CE 211-F students pedagogic learning
FR	FR0 –Realize effective assessment of CE 221 & CE 211-F pedagogic learning: FR1 – Provide feedback through Assessment (survey conducted to identify influences on pedagogic learning) FR2 – Provide a mechanism that incorporates influential factors to student pedagogic learning FR3 – Provide a support tools to implement the intervention framework on identified factors influencing pedagogic-learning
How we want to achieve it?	
DP	DP0 – Effective Assessment of Influences on Pedagogic Learning of CE 221 & CE 211-F DP1 – Analysis of student's responses (Quantitative Analysis) DP1.1 – Mean, Factor Analysis & Regression DP2 – Analysis of influential factors to student pedagogic learning DP2.1 4 – Model of Productive Pedagogy DP2.2 – Uncoupled Design Matrix DP3 – Student support tools necessary to achieve the intervention framework on identified factors influencing pedagogic-learning
PV	PV – Create an intervention framework supporting gap on identified factors affecting pedagogic learning on CE 221 & CE 211-F PV1 – Intervention Concept formulation PV2 – Paradigm Shift Framework PV3 – Lecturer's modification on lecture plans, lecture notes, student activities, and assessments

In order to define when the design solution is acceptable, Thomson (2013) stressed that the input constraints set a hard limit on the values of a quality or metrics.

A key aspect of axiomatic design is the separation between *what a system has to achieve* (functional requirements) and the design choices involved in *how to achieve it* (design parameters).

The analysis of assessing pedagogic learning using AD is presented on the Axiomatic Design Model (ADM) as illustrated in the diagram of figure 1. The ADM diagram shows the decomposition for the analysis of the question "how we want to accomplish", which is mapped to "what we want to accomplish".

2.1 APPLICATION OF DP'S

SPSS software was used for assessment. Factor analysis was used because there are a large number of related variables. The analysis is useful in reducing a large number of related variables to a smaller, more manageable, number of dimensions or components.

2.1.1 Results of DP's - Mean of Responses Analysis on Productive Pedagogies Model

The questions on influences were crafted into Productive Pedagogies (Hill, 2010; Gore, 2013) according to the weighted mean and are organized around a model of four groups of questions:

1) *Recognition of Difference*, understanding multiple forms of knowledge (i.e. cultural knowledge, inclusivity, narrative, active citizenship, and group identity);
2) *Connectedness*, linking learning to a wider world (i.e. connections to the world, problem-based curriculum, background knowledge, knowledge integration);
3) *Intellectual Quality*, making the learner experience more intellectual demands (ie. higher order thinking, meta-language, deep knowledge, deep understanding, substantive conversations, knowledge seen as problematic); and
4) *Supportive Classroom Environment*, expecting students to be responsible for their own learning and expecting high standards (i.e. student control, student support, engagement, explicit criteria or quality performance, self-regulation).

The weighted mean of each cluster was calculated establish the scale of influence illustrated below:

4.5 – 5.0 – Essential, an influence that student always, nearly want to have
3.5 – 4.49 – Very important, an influence student often want to have
2.5 – 3.49 – Important, an influence that student sometime want to have
1.5 – 2.49 – Unimportant, an influence student rarely wants to have
1 – 1.49 – Not applicable, an influence that student never want to have

The use of clusters is an attempt to find the relevance of the descriptors, in which the responses of the students are evaluated by the weighted mean in accordance with the productive pedagogy model presented in table 5.

The result shows that for 1) **For Recognition of Difference**, students perceived that both CE 221 and 211-F *are Very Important*, 2) **For Connectedness**, CE 221 is perceived to be *Very Important* while CE 211-F is said to be *Essential*, 3) For Intellectual Quality, CE 221 is perceived to be *Very Important* while CE 211-F is said to be *Essential*, and 4) Supportive Classroom Environment is perceived to be *Very Important* for both subjects.

The mapping in this design addresses the influences under the 4-category model of productive pedagogy, which results are assessed as *very important* or *essential*. As we toss the processes to the functions, we find that there is a need to make an analysis without bias or pre conception and find a new relation to understand student preferences in the right way. The above idea still circled to teacher preferences, so a multivariate statistics using SPSS software was used in the analysis because it considers more than one dependent variables at a time and controls type-1 errors by considering a set of dependent variables in a multidimensional space, while

accounting the dependent variables as well as the relationships between individual variables and dependent variables.

Table **5**. Pedagogical Framework Influences for CE 221 **& CE 211-F** parallel to Productive Pedagogies

1. Recognition of Difference

Item	Influences Description	Influence scale	
		CE 221	**CE 211-F**
18	Help learn terms and facts in this course	4.69	4.3
19	Help learn concepts and theories in this course	4.67	4.37
20	Develop skill in using materials, tools and/or technology central to this course	4.62	4.36
21	Help learn to understand perspective	4.45	4.15
22	Help learn techniques and method used to gain new knowledge in this course	4.55	4.52
23	Help learn to evaluate methods and materials in this course	4.48	4.17
24	Help learn to appreciate important contributions to this course	4.29	4.03
25	Help develop openness to new ideas	4.45	4.1
26	Help develop an informed concern about contemporary social issues	4.05	3.37
27	Help develop a commitment to exercise the rights and responsibilities of citizenship	4.48	3.74
28	Help develop a life-long love of learning	4.62	4.09
29	Develop aesthetic appreciations	4.21	3.51
30	Develop an informed historical perspective	4.17	3.39
	Over all rating	**4.44, Very Important**	**4.01, Very Important**

2. Connectedness

Item	Influences Description	Influence scale	
		CE 221	**CE 211-F**
31	Develop an informed understanding of the role of science and technology	4.62	4.30
32	Develop an informed appreciation of other cultures	3.93	3.53
33	Develop capacity to make informed ethical choices	4.29	3.79
34	Develop ability to work productively with others	4.52	4.29
35	Develop management skills	4.67	4.43
36	Develop leadership skills	4.48	4.29
37	Develop a commitment to accurate work	4.69	4.7
38	Improve ability to follow directions, instructions and plans	4.64	4.41
39	Improve ability to organize and use time effectively	4.6	4.64
40	Develop a commitment personal achievement	4.57	4.4
41	Develop ability to perform skillfully	4.45	4.45
	Overall rating	**4.5, Very Important**	**4.3,** Essential

Intellectual Quality

Item	Influences Description	Influence scale	
		CE 221	**CE 211-F**
1	Develop ability to apply principles and generalizations already learned to new problem situations	4.69	4.53
2	Develop analytical skills	4.81	4.41
3	Develop problem-solving skills	4.69	4.52
4	Develop ability to draw reasonable inferences from observations	4.43	4.49
5	Develop ability to synthesize and integrate information and ideas	4.5	4.4
6	Develop ability to think holistically, to see the whole as well as the parts	4.48	4.17
7	Develop ability to think creatively	4.74	4.65
8	Develop ability to distinguish between fact and opinion	4.36	3.97
9	Improve skill at paying attention	4.57	4.12
10	Develop ability to concentrate	4.62	4.21
11	Help improve memory skills	4.36	4.12
12	Help improve listening skills	4.31	4.15
13	Help improve speaking skills	4.38	4.12
14	Help improve reading skills	4.17	4.2
15	Help improve writing skills	**4.05**	**3.96**
16	Help develop appropriate study skills, strategies and habits	**4.69**	**4.4**
17	Help study skills, strategies and improve mathematical skill	**4.81**	**4.5**
	Overall rating	**4.51, Very Important**	**4.29** Essential

3. *Supportive Classroom Environment*

Item	Influences Description	Influence scale	
		CE 221	**CE 211 F**
42	Cultivate a sense of responsibility for one's own behavior	4.31	4.03
43	Improve self-esteem/self-confidence	4.38	4.26
44	Develop commitment to one's own values	4.17	4.13
45	Develop respect for others	4.38	4.25
46	Cultivate emotional health and well being	4.36	4.02
47	Cultivate physical health and well being	4.31	4.0
48	Cultivate an active commitment to honesty	4.48	4.4
49	Develop capacity to think for oneself	4.31	3.6
50	Develop capacity to make wise decisions	4.69	4.65
	Overall rating	**4.04, Very Important**	**4.14, Very Important**

The specific analysis used is the exploratory factor analysis to identify the variables apparently resembles to principal component analysis, but has some important distinctions. Methods of factor analysis are used when an underlying factor structure is presumed to exist but cannot be easily represented by a single value. The result is tossed again or mapped to FR's to further refine and understand the challenges that the students are facing so that an appropriate intervention or solution could be adopted.

The results of the analysis and the conclusion, as well as the bibliographic references, are presented in the Part 2 of this document.