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A causal relationship model of learning outcomes model for engineering undergraduate students

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Abstract

The objectives of this research were to develop indicators and learning outcomes for engineering undergraduate student's measurement tools and develop and validate a causal relationship model of learning outcomes for engineering undergraduate students. This study consists of a survey that described the indicators and causal relationship and the result of the study. The survey employed five-point Likert scale questionnaires with 55 items, including four factors, namely human skills, organizational skills, information skills, and knowledge and skills in engineering, and causal relationship. The result from 1,316 engineering undergraduate students showed that the causal relationship model was consistent with empirical data at a moderate level. Learning outcomes are strongly influenced by learning style, followed by achievement goal orientation scale, life-long learning skills, institutional and goal commitments, engineering skill self-efficacy, engineering career outcome expectations, and student status through cooperative education, respectively.

In conclusion, learning style was the most influential but student status through cooperative education was less influential for learning outcomes. However, all variables were important for learning outcomes of engineering undergraduate students.

Keywords: *causal relationship of learning outcomes model, undergraduate students, engineering*

1. Introduction

The rapid growth and globalization affect the economy and society. In the past two decades, higher education institutions have produced graduates in the labor market; however, they must also produce responsible citizens with morals and ethics (UNESCO, 2009). Higher education institutions must be ready in many areas to increase their competitiveness, especially for the development of comparable quality graduates comparing to foreign countries. Their graduates should be able to adapt, have a working skill, and be able to live in the national, religion, cultural, and language diversities (Office of the Higher Education Commission, 2013). In the past, there had been relatively serious concerns about the quality of education; thus, it is indispensable to realize more about how is students' study quality: developed or seeking knowledge, attitude, and skills that are necessary for the institution (UNESCO, 2010). Many changes occur in the educational system, which really needs indicators to assess the learning achievement of students, as learning style has changed from telling or only teachers teaching to enable students can explore new knowledge from everywhere on their own (Pungchompoo, 2016). Furthermore, in the employment context of bachelor graduates, it was found that Thailand can produce graduates into the labor market beyond the demand each year. However, many vacancies are still occurring because the applicants lack the basic skills and specific techniques (UNESCO, 2011), indicating that students, in general, do not show the improvement and develop essential skills during studies period (Arum & Roksa, 2011, as cited in Ursin, Lasonen, Hernandez-Gantes, & Fletcher, 2014).

The society has high expectations on the higher education institutions to operate efficiently and responsibly, concerning their learning outcomes, ability to produce graduates with desirable characteristics that meet the needs in various sectors of society, managing efficiency, and the effectiveness of valuable information to the public. The important information mentioned is such as the cost of graduate production, the number of students, students' dropout rate, students' graduation rate, graduates' employment rate, lectures' quality rate, as well as research and academic works. The production and development of human resources should be planned based on the information that is consistent with the needs of the country in order to drive economic and social development (Office of the Higher Education Commission, 2013). Therefore, indicators and measurement tools for checking basic information, reflect what students should receive from learning, namely learning outcomes should consider, so that all sectors can receive and access information. However, the review of relevant documents and research found that higher education institutions in Thailand, especially the engineering major, high demand major for the labor market, still do not have learning outcomes measurement but still remind less research related to engineering major measurement. Most of the studies related to factors affecting learning inquiry behavior of bachelor's degree in the faculty of engineering (Buacharen, Techapunratanakul, & Buochareon, 2019) causal factors affecting to learning outcomes of nursing students (Petchkong, 2016) competency factors affecting learning outcomes and perception in terms of university overview of students at Chulalongkorn University (Srisai, 2016).

Therefore, this research interested in measuring learning outcomes, as well as to acknowledge other aspects of the education system and the effectiveness of engineering learning and teaching. Being a professional engineer, in addition to having specific knowledge in the field, there must also be able to integrate interdisciplinarity skills and knowledge in a rapidly changing global, social, and technological context, able to work efficiently and effectively with people from diverse backgrounds and cultures. Also, if the students have good learning outcomes, it is contributed significantly to the reputation of the institution, extracting resources for development, and affect the decision making for further study (Nusche, 2008). Moreover, the researcher is interested in developing causal relationships model of learning outcomes for engineering undergraduate students which consisted of 5 variables such as engineering skill self-efficacy (Mamaril, 2014), engineering career outcome expectations (Marra & Bogue, 2006 cited in Concannon & Barrow, 2009), life-long learning skills (Drewery, Pretti, & Barclay, 2016), achievement goal orientation scale (Mamaril, 2014), institutional and goal commitments (Pascarella & Terenzini, 2005), learning style (Ribera, Ribera, BrckaLorenz, & Laird, 2012). For a reason, to propose a development strategy for improving the learning outcome of students for educational institutions and curriculum to prepare students for the labor market of knowledge-based economies in the 21st century.

2. Objective

The main objective of this research was to develop a causal relationship model of learning outcomes for engineering undergraduate students with sub-objectives as follows.

1. To develop indicators and learning outcomes for engineering undergraduate student's measurement tools.

2. To develop and validate the causal relationship model of learning outcomes for engineering undergraduate students.

3. Materials and Method

This survey research divided into 2 phases;

Phase 1 Developing indicators and learning outcomes for engineering undergraduate student's measurement tools

Synthesis components and development of indicators from secondary data: documents, research articles, electronic publications, and research documents. Data collection by using secondary data analysis and making field note. Followed by exploratory factor analysis to develop factor components. According to Hair, Black, Babin, and Anderson (2014), determine the sample size that should be equal to 10-20 times of observed variables. In this research, there were 16 observed variables for confirmatory factor analysis (16 x 20=320) and 21 observed variables for path analysis (21 x 20 = 420); thus the sample size is 1,316 third and fourth-year engineering students who have been learning for a while and are ready to work in the workplace, both during their studies and graduation, with sample random sampling from 11 universities. Five-point Likert scale questionnaire was used as research instruments with .67- 1.00 of validity from five experts, and reliability were between 0.886 to 0.967.

Phase 2 Develop and validate causal relationship model for engineering undergraduate students

This phase aims to develop and validate the causal relationships model of learning outcomes and study the quality level of the causal factors for enhancing learning outcomes by taking the results from phase 1 to analyze the structural equation model.

4. Results

The results of indicators and measurement development for learning outcomes were divided into three parts as follows.

1. General information of respondents

Table 1 Samples Classified by general information

General information	Number	Percentage
Gender		
Male	588	44.68%
Female	728	55.32%
Age		
24 years	73	5.55%
23 years	444	33.74%
22 years	525	39.89%
21 years	274	20.82%
Types of higher education institutions		
Public university	944	71.73%
Private university	250	19.00%
Rajamangala University of Technology	103	7.83%
Open university	19	1.44%

2. The results of indicators and measurement development for learning outcomes for engineering undergraduate students.

2.1) The results of the confirmatory factor divided into four factors, such as human skills, organizational skills, information skills, and knowledge, and skills in engineering (Khampirat, 2008), as detailed in Table 2.

Table 2 Skills and indicators of learning outcomes for students

Skills	Items	β	S.E	z	R^2
Human Skills					
Integrity and Ethical Responsibility	4	.677	.019	36.020	.458
Respect and Honor the Others	2	.519	.023	22.135	.270
Social Skills	3	.741	.017	44.612	.549
Self Confidence and Understanding Diversity	4	.833	.013	63.475	.694
Organizational Skills					
Working Effectively and Efficiently	3	.724	.016	46.422	.524
Membership and Leadership Skills	3	.763	.014	53.850	.583
Entrepreneurship	3	.743	.014	53.155	.552
Knowledge of Business and Public Policy	1	.490	.022	22.036	.240
Information Skills					
Communication Skills	6	.720	.015	47.431	.518
Critical Thinking	5	.770	.013	58.144	.593
Learning Ability	3	.707	.015	46.467	.500
Initiative and Understanding Current Issues in Engineering	2	.716	.015	46.279	.513
Knowledge and Skills in Engineering					
Basic Knowledge in Science and Engineering	2	.664	.017	38.078	.441
Engineering Analysis and Design	5	.791	.013	59.523	.625
Applying Professional Instrument and New Technology	5	.604	.021	29.098	.365
Work Quality and Problem Solving	2	.635	.018	35.961	.403
Adherence to the Code Engineering Professional Ethics	2	.618	.019	33.053	.382
χ^2 = 174.784, *df* = 68, *p* = .000, χ^2/df = 2.570, *RMSEA* = .035, *SRMR* = .022, *TLI* = .983 and *CFI* = .992					

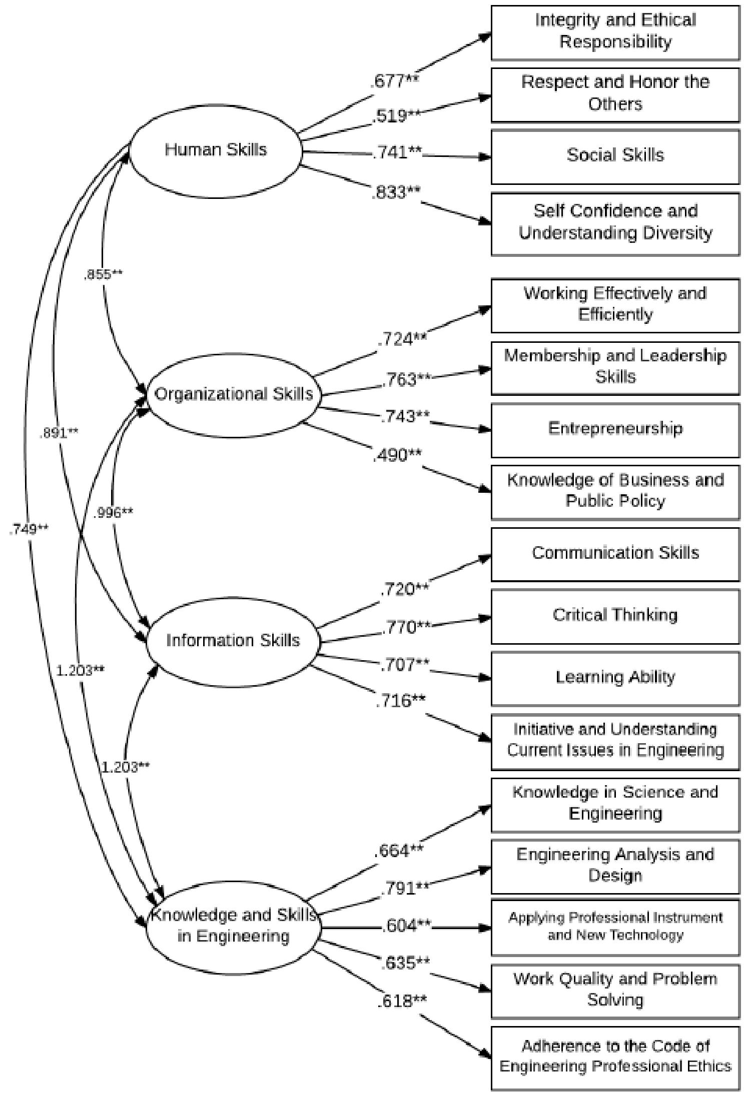

Figure 1 Model for learning outcomes for Engineering undergraduate students

3. Results from constructing the validity of a causal relationship model of learning outcomes for the engineering undergraduate development

3.1 The result of Bartlett's Test of Sphericity was Approx. Chi-Square = 17712.41, *df*= 210, and *p* = .000, indicating that the variables were related or different from zero with statistical significance at .01 and KMO = .936. The result also showed that the correlation matrix of variables was not an identity matrix, and there was enough correlation between the variables to analyze the composition.

3.2 The result from constructing the validity of a causal relationship model of learning outcomes showed that the factors were consistent with the empirical data with factor loading, as detailed in Tables 3 and 4.

Table 3 Total, direct, and indirect standardized effects

Variables	Dependent Variables								
	Learning Outcomes			Lifelong Learning Skills			Engineering Skill Self Efficacy		
	DE	IE	TE	DE	IE	TE	DE	IE	TE
Learning Style		.71**	.71**	.83**	-	.83**	-		
Achievement Goal Orientation Scale	.41**	.05*	.46**	-			-		
Life-Long Learning Skills	.40**	.03	.43**	-			-		
Institutional and Goal Commitments	-	.33**	.33**	-			-		
Engineering Skill Self Efficacy	.09**	-	.09**	-			-		
Engineering Career Outcome Expectations	-	.06*	.06*	-			.66**	-	.66**
Co-op Student	-	.01**	.01**	.60*	-	.60*	.13*	-	.13*
Achievement Goal Orientation Scale	.77**	-	.77**	-			-		
Life-Long Learning Skills	.42**	-	.42**	-			-		
Institutional and Goal Commitments				.79**	-	.79**	-		
Learning Style	-			-			.99**	-	.99**

Table 4 Factor and loading of the causal relationship model for engineering undergraduate students

Observe variables	b	Standardize			Variance/ Residual Variance	R^2
		β	SE	z		
Learning Outcomes						
Human Skills	.82**	.69**	.02	34.53	.53	.47
Organizational Skills	.99**	.83**	.01	66.94	.31	.69
Information Skills	.94**	.81**	.01	60.78	.34	.66
Knowledge and Skills in Engineering	1.00**	.82**	.01	60.38	.33	.67
Engineering Skill Efficacy						
Experimental Skills Self-Efficacy	.84**	.38**	.02	23.60	.86	.14
Tinkering Skills Self-Efficacy	1.00**	.80**	.02	47.43	.37	.63
Engineering Design Self-Efficacy	.97**	.77**	.02	39.39	.40	.60
Engineering career outcome expectations						
Career Success Expectations	1.00**	.66**	.02	27.61	.57	.43
Life Success Expectations	.45**	.01**	.02	18.60	1.00	.00
Life-Long Learning Skills						
Love of Learning	1.00**	.84**	.02	53.19	.30	.70
Information Seeking	.96**	.80**	.02	48.86	.36	.64
Self-Reflection	.91**	.62**	.02	26.90	.62	.38
Resilience	.30**	.01**	.02	24.53	1.00	.00
Achievement Goal Orientation Scale						
Master Goals	1.00**	.70**	.03	26.92	.51	.49
Performance Approach Goals	.74**	.46**	.03	15.59	.79	.21
Performance Avoidance Goals	.54**	.25**	.02	10.23	.94	.06
Institutional and Goal Commitments						
Goal Commitments	.76**	.43**	.03	13.59	.82	.18
Institutional Commitment	1.00**	.69**	.02	28.82	.53	.47
Learning Style						
Effort Regulation	.58**	.42**	.03	13.93	.82	.18
Collaborative Learning	1.00**	.45**	.02	19.72	.80	.20

χ^2 = 213.01, *df* = 140, χ^2/df = 1.52 , *RMSEA* = .05, *SRMR* = .04, *TLI* = .96 and *CFI* = .98

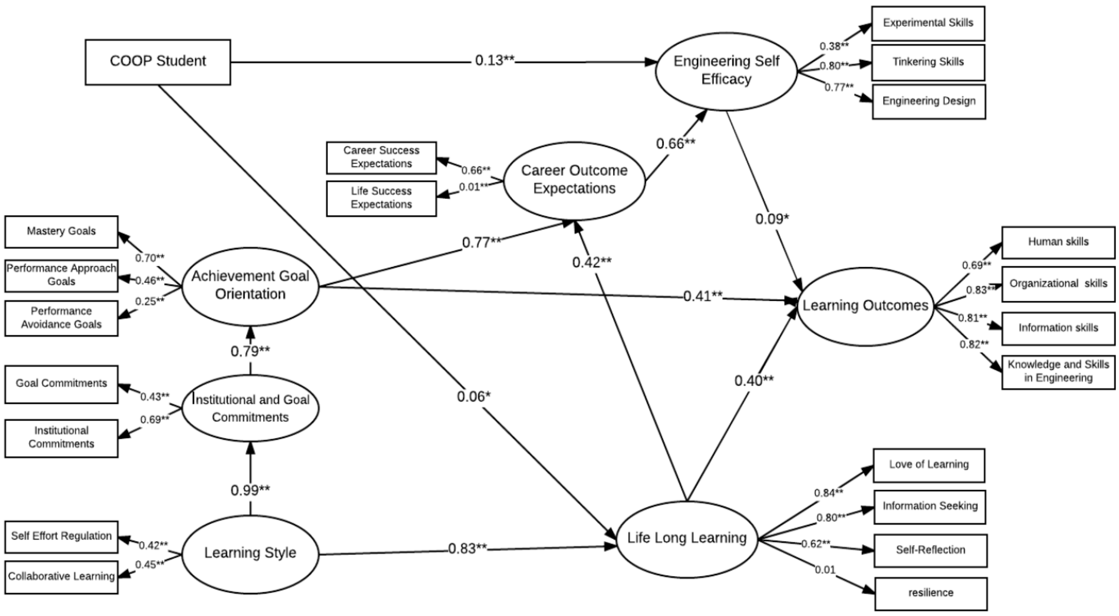

Figure 2 Causal relationship model for engineering undergraduate students

5. Discussion

1. The quality of the learning evaluation tool

The development of indicators for measuring learning outcomes is consistent with Spady's concepts (1994, as cited in Lesch, 1995), which explains that learning outcomes must be observable and measurable. It can be categorized into three areas: knowledge, skills, and attitudes, as well as the characteristics and quality of learners in the 21st century. González and Wagenaar (2008) stated that learning outcomes are the ability level acquired by learners consists of cognitive and meta-cognitive skills, knowledge and understanding, interpersonal, intellectual and practical skills, and ethical values. Learning outcomes indicators measurement developed with the characteristics of Spady (1994, as cited in Lesch, 1995) as follows; 1) reflecting a wide range of knowledge and professional adjustment, and general skills, 2) reflecting valuable knowledge, skills or attitudes, 3) focusing on the results of the learning experience, 4) reflecting the desired of the learning experience, which specifies or does not a process, 5) represents the practice which must succeed in completing the course or program, and 6) able to answer the question "Why should students continue studying this course?" Moreover, these indicators, especially knowledge and skills in engineering and academic or other, generally measure the learning outcomes based on the concept of Spady and reflect the definition of employability skills, which are the skills or the personal value of new graduates ready to enter the work system.

2. The quality of indicators in each factor

The results of confirmatory factor analysis show that the variable with the highest weight as following: human skill measurement model is self-confidence and understanding of diversity, the organizational skill measurement model is collaborator and leader skill, information skills are analytical thinking and knowledge and skills in engineering is an analysis and engineering design. Overall, it presented that life and working environment in the rapidly changing in the technology era need graduates with qualifications rather than thinking skills and academic knowledge. Thus, students must develop life skills, emotional skills, and careers to stand out in a complex and competitive environment.

2.1 Self-confidence and understanding diversity refers to the ability to self-motivate and self-confidence in order to handle the challenge and deal with feedback effectively, as well as being able to adapt to a responsible job professionally. It is important and has a strong correlation in everyday life. Self-confidence, the feeling of acceptance and ability of themselves, influence motivation, and self-regulation (Bandura, 2006). Thinking and treating others while understanding diversity will help managing differences between individuals, society, politics, economic status, and culture, where else, seeing and understanding diversity is the respect of human values (Mann & Dolan, 2003).

2.2 Membership and leadership skills refer to being able to motivate and influence other people's work with a diverse team and create a proud atmosphere for the team, which is important and necessary to work in a diverse organization. Engineers must have the ability to work individually and teamwork, and able to work effectively as a member and leader in the team, especially, multidisciplinary work (Engineers Canada Accreditation Board, 2015), which is consistent with the skills needed in the 21st century, and being able to guide and lead other people (Partnership for 21st Century Skills, 2009). Having membership or follower skills can help build relationships with leaders and teams (Hurwitz & Hurwitz, 2015).

2.3 Critical thinking refers to having skills and ability to think critically, analytically, systematically, able to determine important questions, and assess self-knowledge and ability for continuous work's development. People with critical thinking skills will be able to build credibility on their decisions, as it is relevant to assess the quality of the data sources, the facts, the observed phenomena, and findings from researches. All of these depend on the type of industry, the result of the rapid change and development of technology, and a large amount of data. Engineering students need to develop and apply critical thinking skills in their work or academic projects, solving complex problems faced and evaluating important options (Kobzeva, 2015). Analytical skills in engineers will be different from other fields (Douglas, 2012), which will help students to experience success in work and life in the future (Živkoviü, 2016).

2.4 Engineering analysis and design refer to the ability to apply knowledge, processes, techniques, and engineering design, conducting experiments to solve engineering problems, including knowledge and understanding of the impact of engineering solutions, and with perseverance and patience to complete the engineering work. It is because engineering analysis and design is the process of inventing systems, components, or processes to meet the essential needs that result from the use of technology to meet human needs or to solve problems (Khandani, 2005).

3. Analyzing the causal relationship of the learning outcomes for engineering undergraduate students' model

The result of the causal relationship model analysis demonstrates that the learning style had the most significant indirect effect on the learning outcomes. Learning style indicators measured in this research included effort regulation and collaborative learning. It shows the effort of self-management, study hard for getting the best results, the exchange of opinions related to study courses with others, that inspire characteristics of self-control in learning, gaining skills, and determination to succeed in studies and work. It is an essential component that predicts academic success, both for students and other environmental factors, and affects the commitment to the program and educational goals. Moreover, this finding is consistent with Graunke and Woosley (2005) that discipline and good interaction with the faculty are the critical variables that determine the academic success of students. Also, it is consistent with Zumbrunn, Tadlock, and Roberts (2011), which found that self-regulation learning was the important predicting achievement and motivation of the learners. It is the process helps learners to have better behavior and better learning skills (Wolters, 2011) and increases academic achievement (Harris, Friedlander, Sadler, Frizzelle, & Graham, 2005; Zimmerman, 2008) as the learners have a follow-up plan (Harris et al, 2005) and assess learning (de Bruin, Thiede, & Camp, 2011) independently.

6. Conclusion

Learning style was the most influential but student status through cooperative education was less influential for learning outcomes. However, all variables were important for learning outcomes of engineering undergraduate students. Those involved in the development and promotion of learning outcomes should focus on development and promotion of holistic learning outcomes in the future.

7. Recommendation for the use of research

The result of this research can be used as an educational strategy and as a tool for developing a new curriculum to improve engineering students' learning outcomes and preparing the students for the labor market of knowledge-based economies in the Twenty-first Century.

Recommendation for next research

More studies should emphasize designing activities that help the students develop essential skills to improve the learning outcomes.

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