Revolutionizing Education with the Awareness of the Value of Knowledge Concepts

By

Kittipong Techapanichgul

Submitted to the System Design and Management Program

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Abstract

A high quality education is more critical than ever in the knowledge-based economy. Although many national governments allocate significant financial resources to improve education quality, an insufficient number of quality teachers, especially in developing countries, appear to retard the quality improvement of education.

To tackle the scarcity of quality teachers, this study presented an alternative approach where high-level system architecture of intrinsically motivated learning systems is proposed. The system architecture is designed to maximize students' role in learning to immediately cope with the shortage of quality teachers while teacher quality improvement programs should be implemented in parallel to increase the number of quality teachers. The proposed system architecture is intended to be used as a blueprint for designing various forms of intrinsically motivated learning systems whose common objective is to enhance students' motivation to learn on their own as well as helping students cultivate their active and self-directed learning mindset.

Extensive literature across disciplines and education reports were first reviewed to synthesize a set of system design principles of a successful learning system. Together with case studies in Thailand, the system architecture was specifically designed to manage educational challenges in other developing countries where conditions might be similar to those in Thailand. System architecture frameworks (e.g., the needs-to-goals framework) were then used to guide the development of the high-level system architecture of intrinsically motivated learning systems, resulting in the software prototype that participating students have actually interacted with. Two questionnaires were also constructed and distributed to collect data from participating students in order to measure changes in their intrinsic motivation levels. The qualitative analysis suggested that some students using the software prototype learned to think more systematically and started recognizing the value of concepts learned in high school. However, whether or not students have higher intrinsic motivation is inconclusive due to insufficient number of active participants.

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First and foremost, I would like to thank my parents for their unconditional love and supports, which show me what true love feels like. They not only initially funded my academic pursuits but also greatly understand my indefinite learning desire, leading to a lifetime opportunity to enjoy invaluable learning experience at Massachusetts Institutes of Technology.

At MIT, I learned to become a thoughtful thinker, an active change maker and a more responsible global citizen to make this world a better place for everyone. MIT and its culture encourage me to dare to dream of "educational equality" in my beloved country, Thailand. As I strongly believe that the smaller gap of educational inequality will somewhat reduce "economic inequality", I got interested in education innovations and began tackling a problem of education quality and inequality in Thailand through this thesis.

I would like to express my sincere gratitude to my thesis supervisor Pat Hale and my thesis committee Professor Mitchel Resnick who consistently provide insightful advices, enlightening guidance and major inspirations to spend days and nights to deliver the best work. Without their supports to the greatest extent, I would not be able to come this far. In addition, I am grateful to Professor Richard Larson who gave me a chance to work as a research assistant in the "Guided Learning Pathways" research project where I gained greater understanding in Jean Piaget's discoveries in children's learning process.

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Lastly, I would like to excerpt the "Impossible Dream" lyrics in English by Joe Darion and in Thai by a Thai milady to anyone who shares the dream of educational equality in Thailand and in this world.

To dream ... the impossible dream	ขอฝันใฝ่ในฝันอันเหลือเชื่อ
To fight ... the unbeatable foe	ขอสู้ศึกทุกเมื่อไม่หวั่นไหว
To bear ... with unbearable sorrow	ขอทนทุกข์รุกโรมโหมกายใจ
To run ... where the brave dare not go	ขอฝ่าฟันผองภัยด้วยใจทะนง
To right ... the unrightable wrong	จะแน่วแน่แก้ไขในสิ่งผิด
To love ... pure and chaste from afar	จะรักชาติจนชีวิตเป็นผุยผง
To try ... when your arms are too weary	จะยอมตายหมายให้เกียรติดำรง
To reach ... the unreachable star	จะปิดทองหลังองค์พระปฏิมา
This is my quest, to follow that star	ไม่ท้อถอยคอยสร้างสิ่งที่ควร
No matter how hopeless, no matter how far	ไม่เรรวนพะว้าพะวังคิดกังขา
To fight for the right, without question or pause	ไม่เคืองแค้นน้อยใจในโชคชะตา
To be willing to march into Hell, for a Heavenly cause	ไม่เสียดายชีวาถ้าสิ้นไป
And I know if I'll only be true	นี่คือปณิธานที่หาญมุ่ง
To this glorious quest	หมายผดุงยุติธรรม์อันสดใส
That my heart will lie peaceful and calm	ถึงทนทุกข์ทรมานนานเท่าใด
When I'm laid to my rest	ยังมั่นใจรักชาติองอาจครัน
And the world will be better for this	โลกมนุษย์ย่อมจะดีกว่านี้แน่
That one man, scorned and covered with scars	เพราะมีผู้ไม่ยอมแพ้แม้ถูกหยัน
Still strove, with his last ounce of courage	คงยืนหยัดสู้ไปใฝ่ประจัญ
To reach ... the unreachable star	ยอมอาสัญก็เพราะปองเทิดผองไทย

"Education may be the only thing that makes the impossible dream possible."

Kittipong Techapanichgul
System Design and Management Fellow

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1. Introduction

1.1. Thesis Motivation

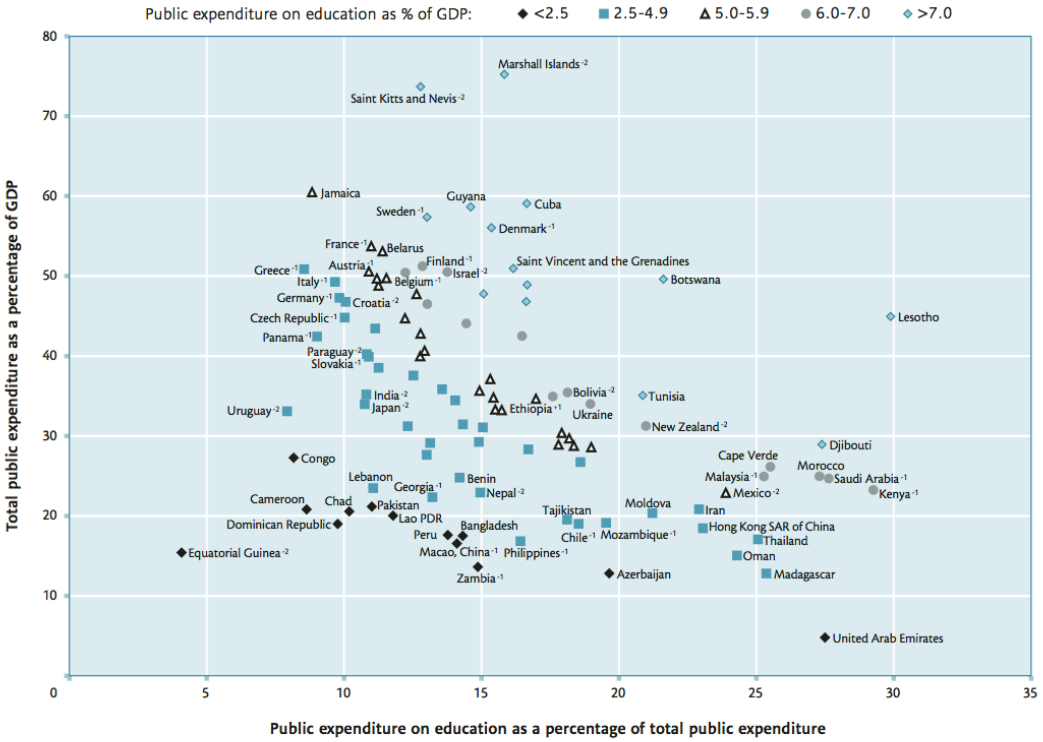
"*What you make of your education will decide nothing less than the future of this country. The future of America depends on you,*" Barack Obama said in his speech on importance of education[1] on September 8, 2009. I strongly agree with him that among the key factors in national development, education appears to be the most promising driver of sustainable development. Because people are the foundation of a nation and education obviously leads to human development, it is indispensable for every nation not only to constantly evaluate the effectiveness of its national education system but also to push propitious education reforms in order to cultivate "educated and responsible citizens". This notion corresponds to the *Declaration on Science and the Use of Scientific Knowledge* at the world conference on science in Budapest in 1999:

> *"Today, more than ever, science and its applications are indispensable for development. All levels of government and the private sector should provide enhanced support for building up an adequate and evenly distributed scientific and technological capacity through appropriate education and research programmes as an indispensable foundation for economic, social, cultural and environmentally sound development. This is particularly urgent for developing countries.[2]" – UNESCO*

[1] Obama, B. (2009, September), *Obama's Speech on Importance of Education*. Retrieved May 10, 2011 from http://www.upi.com/Top_News/2009/09/08/Obamas-speech-on-importance-of-education/UPI-21501252429738/#ixzz1Lyn6NYyh

[2] UNESCO. (1999). *The Declaration on Science and the Use of Scientific Knowledge*. Retrieved April 9, 2010 from http://www.unesco.org/bpi/science/content/docum/declare.htm

It is clear that the vision of education as the key for development is conceived as a fundamental truth. Following the recommendations of the Association of American Colleges and Universities 2005 report[3], education systems should promote the development of critical and creative thinking; foundational knowledge and fundamental skills; appropriate habits; and beneficial personal values and positive attitudes, which will allow people to conscientiously cope with the never-ending challenges inside the nation and in the world around them.



Notes: Data on total public expenditure (non-education and education expenditure combined) for all levels of government combined (central, regional and local) are obtained from ministries of education by the UIS in absence of an authoritative international source. Because it is not the mandate of the UIS is to publish national accounts data, these data are not included in the UIS database.
+1 Data refer to 2006; -1 Data refer to 2004; -2 Data refer to 2003.
Sources: UNESCO Institute for Statistics, Statistical Table 13; UIS calculation based on World Development Indicators.

Figure 1: Public Education Expenditure as a Percentage of Government Expenditure and Total Government Expenditure as a Percentage of GDP, 2005

As shown in Figure 1[4], although many governments have been responding to this fundamental truth by allocating a large proportion of their national budget to education,

[3] AACU. (2005). *Liberal Education outcomes – A Preliminary Report on Student Achievement in College*. Retrieved May 12, 2010 from http://www.aacu.org/advocacy/pdfs/leap_report_final.pdf
[4] UNESCO. (2007). *Global Education Digest 2007*. Retrieved on May 11, 2011 from http://www.uis.unesco.org/template/pdf/ged/2007/EN_web2.pdf

a problem of education quality is still prevalent in many countries, particularly in developing countries. Memon[5], for example, pointed out that even though Pakistan experienced a massive growth in number of students enrolled due to the government's initiatives in uplifting the quality and quantity of education, the poor qualification of teachers retarded their education improvement initiatives. The inadvertent results reflect in the percentage of students dropping out before grade 5 at 50% and the percentage of low adult literacy rate of 45%. This particular case in Pakistan reveals that the inferior teacher quality can be the principal obstacle to improving education despite the availability of financial resources.

Key Education Indicators	Pakistan	India	Sri Lanka
Adult literacy rate % (1999)	45	56. 5	91. 4
Female literacy rate % (1999)	30	44. 5	88. 6
Primary enrolment (% gross (1997)	74	100	109
Secondary enrolment (gross) % (1997)	26	49	75
Percentage of children dropping out before grade 5 (1995-1999)	50	48	3
Public expenditure on education (as % of GNP) 1995-97	2. 7	3. 2	3. 4

Table 1: Key Education Indicators Comparing Pakistan to Other Countries in the Same Region

Unequal access of students to qualified teachers appears to be another important hindrance. A U.S. study[6] in 2007 by Motoko Akiba, Gerald K. LeTendre, and Jay P. Scribner reported that a major obstacle in federal and state efforts to increase the quality of teaching workforce and student achievement is the students' access to qualified teachers. Obviously, the student's poverty imposes a great barrier to access high quality teachers, which intensifies educational inequality. Thus, the inferior quality

[5] Memon, G.R. (2007, Spring). Education in Pakistan: The Key Issues, Problems and The New Challenges. *Journal of Management and Social Sciences 3*(1), 47-55. Retrieved May 12, 2011 from http://www.biztek.edu.pk/downloads/research/jmss_v3_n1/5%20EDUCATION%20IN%20PAKISTAN.pdf

[6] Akiba, M., LeTendre, G. & Scribner, J. (2007, July). Teacher Quality, Opportunity Gap, and National Achievement in 46 Countries. *Educational Researcher 36*(7). 369-387. Retrieved May 12, 2011 from SAGE Journal Online

of teachers and unequal access to qualified teachers are two salient problems in national education system in both developed and developing countries.

Surprisingly, the United States, which is one of the leading developed countries, is also facing the shortage of qualified teachers in schools. Although Daniel Sturtevant's thesis[7] suggested that one possible solution is to increase the standard wage of teachers to attract quality people to become quality teachers, it would be difficult for developing countries to immediately execute this solution due to lower available financial resources, resulting in inability to pay teachers higher salary. As a consequence, many high-quality people in developing countries are likely to work in more profitable industrial sectors than in academia to generate a higher income.

Even though it is indispensable for every nation to create more qualified teachers, it might be time to revolutionize education systems by introducing a complementary learning system that can intrinsically motivate students to learn more on their own. This education revolution would cultivate a new student's focus on self-directed learning to tackle the problem of inadequate numbers of quality teachers until resources are available.

1.2. Thesis Objective

The primary thesis objective is to develop a system architecture used as a blueprint for intrinsically motivated learning systems. The common objective of intrinsically motivated learning systems is to enhance intrinsic motivation of high school students in learning, particularly students in developing countries; to focus more on learning activities inside and outside school and to learn on their own without

[7] Sturtevant D.J. (2008, September). *America Disrupted: Dynamics of the Technical Capability Crisis*. Retrieved May 12, 2011 from https://lgosdm.mit.edu/VCSS/servlet/LoadFile?VIEW=4&file=/Thesis/25371/Sturtevant%20thesis.pdf

teachers' presence. The intrinsically motivated learning systems are also expected to indirectly cultivate an active learning attitude by assisting students to question themselves why they learn[8] and develop their own learning goals accordingly. The active learning attitude would gently nurture the development of the students' lifelong learning habits. It is important to note that the system architecture is not intended to replace any existing education systems and teachers. Instead, this system architecture is designed to mitigate the problem of inadequate teacher quality, especially in developing countries, while teacher quality improvement programs could be implemented in parallel to heighten the quality of teachers at the same time.

Although teachers are the main source of students' motivation at school and the most indispensable education system component, there are three main reasons why the system architecture for intrinsically motivated learning systems is designed to minimize the role of teachers.

- First, teachers lacking motivational skills can undermine student motivation.
- Second, high school students tend to exhibit low attention span, interest and even desire to learn when the concepts being taught in classes are not well articulated because of under qualified teachers. Hence, the concepts seem meaningless to them in the first place, which creates a negative impression and even disdain for learning on that particular subject.
- Third, even though recruiting high quality teachers seems to be a quick and effective solution to tackle this motivation problem, it is difficult for developing countries to nurture and carry over both high quality teachers and fundamental

[8] Identifying own needs help develop "a sense of purpose", which is one of the three minimum elements for intrinsic motivation – Pink, D. (2009). Drive: The Surprising Truth About What Motivates Us, Retrieved May 11, 2011 from http://www.danpink.com/drive

learning infrastructure (e.g., school, museum, public library, etc.).

1.3. Hypothesis

Presuming that student awareness of the subtle connections between learning activities and their professional activities would increase student motivation to learn, the idea of designing a system architecture for intrinsically motivated learning systems that aids students to recognize these subtle connections is proposed as an unprecedented approach to enhancing student motivation in learning. Although a reading educator, Sharon Draper, ideated that when children can make meaningful connections between reading and their own lives, their motivation to read becomes intrinsic[9], there is no strong evidence to support that if a learner can make meaningful connections between learning activities (e.g., reading) and professional activities (e.g., activities of their own lives), his or her motivation in learning would be intrinsic. For this reason, along with novel system architecture, the hypothesis of "*whether or not the recognition of subtle connections among concepts, skills and professions (future roles in a society) is a contributing factor in raising student motivation in learning*" is also tested in this thesis. The thesis was planned to validate the defined hypothesis by using online questionnaires where the data analysis would help gain more understanding of whether or not visible connections among knowledge concepts, skills and desired professions can intrinsically motivate students to learn on their own without teacher's presence.

1.4. Methodology

This thesis begins by reviewing a wide range of interdisciplinary literature and research on worldwide education systems, learning theory and human motivation—

[9] Braunger, J., & Lewis, J. (1998). Building a knowledge base in reading, 2nd edition. Newark, NJ: International Reading Association.

particularly student motivation. The outstanding literature and research are carefully analyzed to identify convergent insights in order to develop a set of system design principles, which are subsequently interwoven to design a system architecture for intrinsically motivated learning systems to meet the defined objective of this thesis. Since the system architecture is designed to work in practice in both developed countries and developing countries, education systems of selected developed countries as well as a selected developing country Thailand are examined to identify major challenges and limitations in the existing education systems worldwide. In addition, notes gathered from classroom observations and personal interviews with Thai high school teachers in Khon Kaen, a remote area in Northeastern Thailand, are included to provide local perspectives. With these local insights, the system architecture can be designed to manage education system shortcomings in other developing countries where conditions are similar to those in Thailand. Several frameworks in ESD.34 system architecture are then utilized in the design process of the system architecture to control the risk of system failures when implemented in practice. The designed system architecture is then used as a blueprint to develop a prototype under the name of REACH, which was implemented with Flash™ technology. Finally, the opinions of students interacting with the prototype were collected via two online questionnaires for eventual analysis where the objective is to validate the defined hypothesis and the practicality of the designed system architecture.

1.5. Thesis Organization

Chapter 1 provides an overview of the thesis outline. Chapter 2 reviews educational statistics of selected successful countries in education to generalize common characteristics of a successful education system. Chapter 3 describes two

selected cases in Thailand, including a report on class observations and student interviews, as well as Thailand education system challenges. The objective of chapter 3 is to identify key concerns in developing countries whose conditions might be similar to those in Thailand. Chapter 4 provides a summary of key concepts in lifelong learning, self-directed learning, constructivism, constructivism and cultural-historical psychology, which are used to synthesize design principles for the system architecture development of intrinsically motivated learning systems. Interesting findings in research on human motivation and vicarious learning are introduced in chapter 5 to provide further understandings of how to successfully design a learning system that can enhance students' motivation in learning. Based on those learning system design guidelines, the designed system architecture for IMLS is proposed in chapter 6, while the development of a conceptual design and the implementation of a prototype are presented in chapter 7. Next, chapter 8 discusses the design rationale of the questionnaires used for identifying associations displaying in the prototype and for validating the hypothesis. Chapter 8 also offers the survey results and analysis, leading to thesis conclusion and suggested future research in chapter 9 and 10 respectively.

2. Characteristics of Successful Education Systems

Successful companies across industries are likely to share a set of common characteristics. Likewise, successful education systems across countries tend to share some mutual characteristics that led them to the excellence. Because education systems basically consist of two main system components, which are learner entity and mentor entity, scrutinizing common characteristics of successful learners (or students) and schools (where a group of mentors cooperate together) across countries would unveil some promising success drivers, which can subsequently underlie a set of fundamental system design principles of successful learning systems.

Because successful education in science strongly correlates with the creation of new knowledge, new technologies and innovations, leading to economic growth and social development, interesting findings on top-performing students and schools in science from various OECD[10] countries are firstly introduced in this chapter. After that, common characteristics of top-performing learners and schools across countries are then identified. Along those finding and the common characteristics, an in-depth analysis is conducted to shed the light on what fundamental principles of education system design should be proposed and added into the list of the learning system design guideline. At the end of this chapter, a study of specific characteristics of the education system in Finland, the best country in providing high quality education, is presented to fill in any missing principles in the preceding list of the learning system design guideline.

[10] Organization for Economic Co-operation and Development

Unless otherwise noted, information for this chapter mostly comes from "Top of the class – High Performers in Science in PISA 2006[11]" by OECD.

2.1. Definition of Top Performing Students

To classify the proficiency of students in science, the PISA 2006 report has developed six proficiency levels where the description presents in the following table. PISA defined top performers as the students in level 5 and 6 on this proficiency scale.

Proficiency Level	Student Performance Description
1	Students have limited scientific knowledge and are only able to provide possible explanation in familiar context
2	Students draw conclusions from simple investigations
3	Students can identify clearly scientific issues in a variety of contexts and apply scientific principles, facts and knowledge to explain phenomena
4	Students can address specific phenomena and situations, making the inferences about science or technology, and they can reflect and communicate decisions using scientific knowledge and evidences
5	Students can identify the scientific components of many complex life situations, apply both scientific concepts and knowledge about science to these situations, and compare, select and evaluate appropriate scientific evidence for responding to life situations. Student at this level can use well-developed inquiry abilities, link knowledge appropriately and bring critical insights to situations. They can construct explanations based on evidence and arguments based on their critical

[11] OECD. (2006). Top of the class – High Performers in Science in PISA 2006. Paris, France. OECD Publication.

	analysis
6	Students can consistently identify, explain and apply scientific knowledge and knowledge about science in a variety of complex life situations. They can link different information sources and explanations and use evidences from those sources to justify decisions. They clearly and consistently demonstrate advanced scientific thinking and reasoning, and they demonstrate willingness to use their scientific understanding in support of solutions to unfamiliar scientific and technological situations. Students at this level can use scientific knowledge and develop arguments in support recommendations and decisions that centre on personal, social and global situations.

Table 2: Definition of Top Performers in Science, Reading and Mathematics

2.2. Findings on Top-Performing Countries in Education

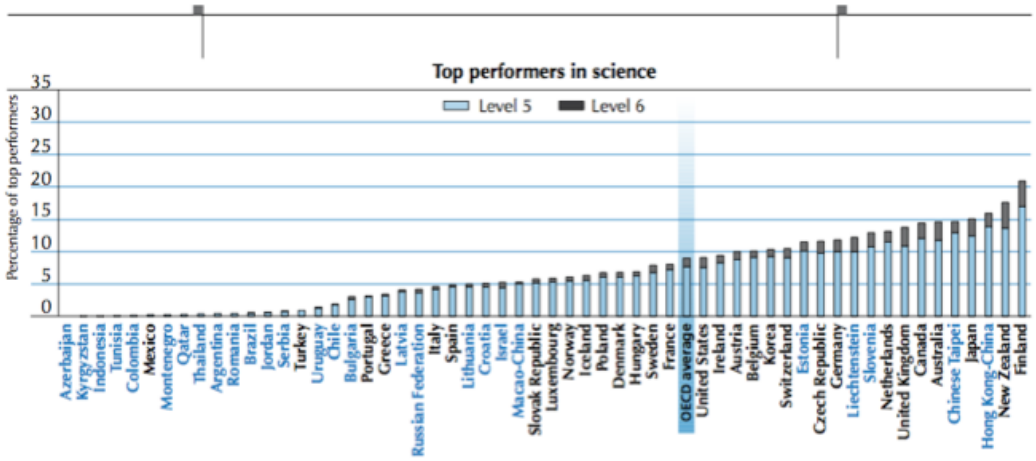


Figure 2: Top Performing Countries in Science

According to the PISA report, 20% of all 15-year-old students in Finland were considered top performers[12] in at least one of the subject areas of science, mathematics

[12] Top performers are students at level 5 and level 6 on the proficiency scale (of the PISA 2006 Science assessment). More details in the PISA report page 26

and reading as shown in figure 2. The following runner-ups were New Zealand, Hong Kong, Japan and Taiwan respectively. Surprisingly, UK and USA, where many people believe in the effectiveness of their education system, ranked 8th and 20th in the proportion of top performers in science.

As shown in the figure 3, although US and UK had the unexpected proportion of top performers, US accounted for 25% of the total number of top performers across all PISA countries because of its country size while Finland, the country with the highest top performer proportion, made up only 1% of the total population of the top performers because of its small size.

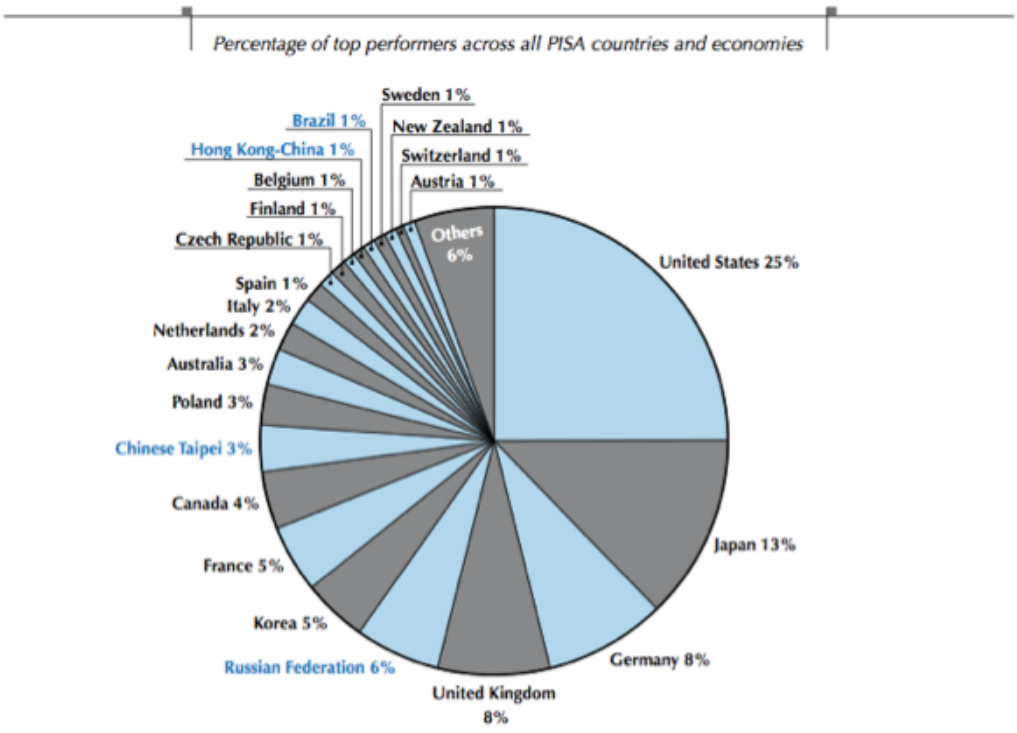


Figure 3: Top Global Talent Pool - A Perspective from PISA

2.3. Characteristics of Top-Performing Schools

To gain more understanding about the distribution of top performers among schools, PISA conducted a survey of school principals and found out that top performers

tend to attend schools where other top performers attended. In other words, most top performers are concentrated in a few schools. For example, more than 90% of students in Finland, Australia and New Zealand are in schools attended by top performers. However, the evidence suggests that a concentration of top performers in certain schools is **not** a pre-requisite for archiving high proficiency levels.

Interestingly, Nordic countries (Finland, Iceland, Norway, Sweden and Poland) show little variation in student performance among their schools. To put it differently, top-performing students are distributed among schools not concentrated in just a few schools. Thus, identifying specific characteristics of the education system in Nordic countries could help reveal a reliable approach to evenly distribute educational excellence in science among schools, leading to a smaller gap of educational inequality within a country. Since Finland is the best Nordic country providing high quality education, the last section in this chapter is devoted to analyze Finland education system to synthesize learning system design principles.

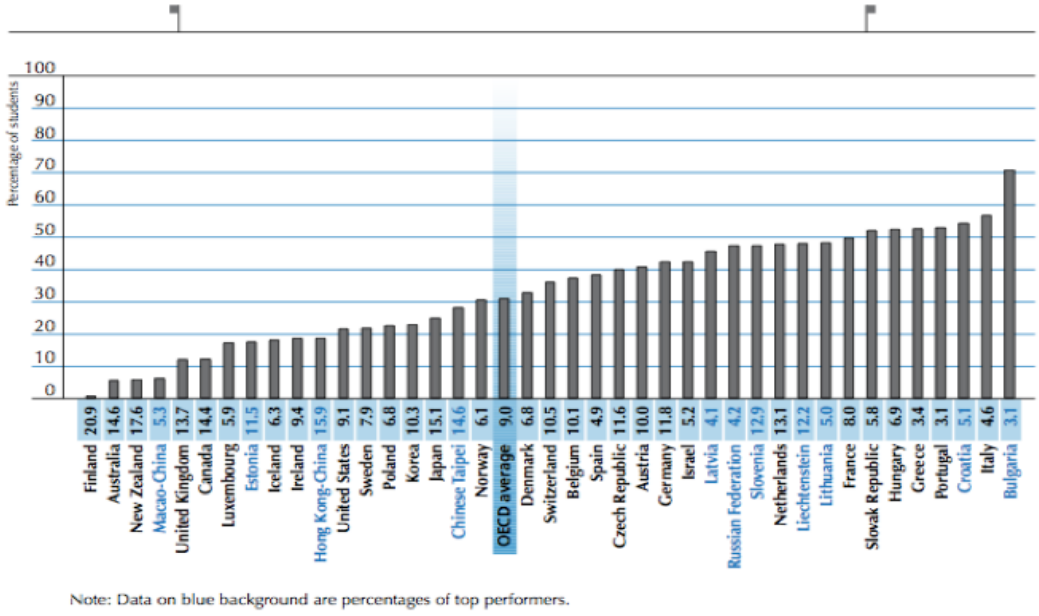


Figure 4: Percentage of Students in School with no Top Performers

In addition, PISA found that top performers are prone to attend schools where the student body comes from a more socioeconomic advantaged background. This evidence supports that schools with large proportion of students who come from a more advantaged background often provide a stronger learning program with demanding curriculum and instruction. Also, such schools have an ability to attract the best teachers seeking for a high-productive teaching environment, which reflects in the higher student performance than the average. However, it is not always true to say that students who come from a more socioeconomic advantaged background will have a better chance of being top performers, which corresponds to a study in the December 2008 issue of *Psychological Science* reporting that children of parents with a high socioeconomic status tended to express more "**disengagement**" behaviors than their less fortunate peers[13]. This contradictory finding implies that some students with an advantage background could sometimes disengage from learning activities than peers with a socioeconomic disadvantage background. For this reason, the socioeconomic status of student body is not an indispensible component for top performing schools.

2.4. Characteristics of Top-Performing Students

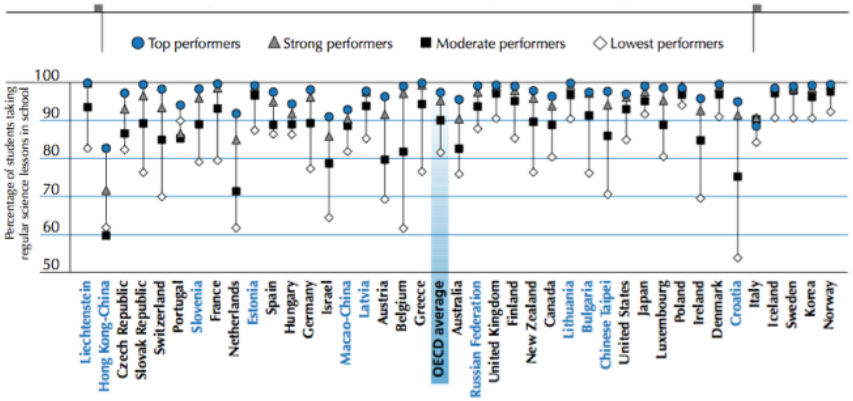


Figure 5: Regular Science Lessons in School, By Performance Group

[13] Kraus, M.W., Keltner, D. (2008). Signs of Socioeconomic Status: A Thin-Slicing Approach. *Psychological Science* 20 (1), 99–106. Retrieve May 10, 2011 from http://pss.sagepub.com/content/20/1/99

Top-performing students in 12 out of 28 OECD countries reported that they had a greater exposure to a teaching approach where teachers show either scientific physical models or present potential applications of science being taught in the classes. Since these two teaching approaches appear to be the most effective methods for top performing students, the learning systems that offer students insights into how they might use scientific understandings in multiple roles in a society (e.g., citizens, workers, inventors, innovators) are likely to nurture top-performing students in science. While focusing on application of science is an effective learning approach for top-performing students, the engagement-based teaching approaches (e.g., scientific investigation, hand-on experiences, and student interactions) can generate a greater interest in science in ordinary students because of the enjoyment of freedom to explore and interactions with others. Hence, good learning systems should provide a mix of different teaching strategies to serve the dissimilar characteristic of the student body.

When looking closer to the learning experience of the top-performing students, PISA found that top performers receive more science lessons at 4 hours a week while the lowest performing group receive only 2 hours a week. This finding confirmed the general notion that the more time a student seriously devotes to scientific education; the more understanding in science the student develops. Moreover, activities outside of school or in conjunction with school could reinforce students in learning. The PISA 2006 survey found that top-performing student group engages in science-related activities more than other student groups. The activities include reading science magazines or articles often (38% among OECD top performers), watching TV programs about science often (32%), visit websites about science topics (21%) and buying books on science topics (14%). This discovery shows a strong correlation between student performance

and student-initiated activities. It is inferable that awareness and accessibility to available learning materials in articles or on TV program (and websites) appear to be the key factors that help promote student performance outside school. Besides, the level of enjoyment and interest also highly affect the performance of top students. Specifically, more than 80% of top performing students reported that they enjoy learning science, are interested in learning science and have fun in learning whereas less than 50% of lowest performance student group reported the same feelings. For that reason, a learning activity should be organized in a way that increases enjoyment, interest and fun, which will consequently attract students to learning.

Average percentage of students by performance group in OECD countries reporting high or medium interest in the following:				
Interest in different science topics	Lowest performers %	Moderate performers %	Strong performers %	Top performers %
Human biology	56	67	74	77
Topics in chemistry	37	45	59	72
Topics in physics	39	44	57	69
Topics in astronomy	36	50	62	67
Ways scientists design experiments	38	43	50	58
The biology of plants	38	44	51	56
Topics in geology	29	37	47	52
What is required for scientific explanations	29	32	41	51
Average percentage of students by performance group in OECD countries agreeing or strongly agreeing with the following:				
Enjoyment of learning science	Lowest performers %	Moderate performers %	Strong performers %	Top performers %
I enjoy acquiring new knowledge in science.	49	62	78	87
I am interested in learning about science.	46	57	73	85
I generally have fun when I am learning science topics.	48	57	72	83
I like reading about science.	33	43	60	75
I am happy doing science problems.	30	37	53	68

Figure 6: Interest in Different Science Topics and Enjoyment of Science

Equally important, the motivation to learn science seems to be another key driver for majority of top performers in science because they believe that the study will help them succeed in future studies and career. This inference came from the results for the average percentage of students on statement concerning their *instrumental motivation to learn science* as shown in the figure 7.

Average percentage of students by performance group in OECD countries agreeing or strongly agreeing with the following:				
Instrumental motivation to learn science	Lowest performers %	Moderate performers %	Strong performers %	Top performers %
I study science because I know it is useful for me.	55	62	73	81
Studying my science subject(s) is worthwhile for me because what I learn will improve my career prospects.	52	56	67	76
Making an effort in my science subject(s) is worth it because this will help me in the work I want to do later on.	58	58	66	75
What I learn in my science subject(s) is important for me because I need this for what I want to study later on.	51	50	58	70
I will learn many things in my science subject(s) that will help me get a job.	51	52	59	67

Figure 7: Instrumental Motivation to Learn Science and the Importance of Doing Well in Science

81% of top performers study science because they believe science is useful for them while 76% of top performers learn science because understanding in science will expand career opportunities. In the same vein, 75% of top performers feel motivated to learning science because learning will help them in the work they want to do later on. As shown in the figure 7, the large proportion of top performers agree with statement 2 (studying my science subject is worthwhile for me because what I learn will improve my career) and statement 3 (making an effort in my science subject is worth it because this will help me in the work I want to do later on), which could be conceived that the motivation to learn is often inspired by potential job opportunities in which knowledge in science is a must.

Average percentage of students by performance group in OECD countries agreeing or strongly agreeing with the following:				
Self-concept in science	Lowest performers %	Moderate performers %	Strong performers %	Top performers %
I can usually give good answers to test questions on science topics.	49	60	76	87
When I am being taught science, I can understand the concepts very well.	44	53	69	82
I learn science topics quickly.	41	50	66	80
I can easily understand new ideas in science.	42	49	65	79
Science topics are easy for me.	36	40	55	70
Learning advanced science topics would be easy for me.	42	39	52	68

Figure 8: Self-Concept in Science

Last but not least, the self-efficacy and self-concept (also called self-perspective) of a student appear to be two additional key success factors for great performing in school. Self-efficacy in this context means the confidence level of a student in tackling specific tasks while the notion of self-concept is the belief level in student academic ability. As shown in the figure and table below, PISA found that top performers have strong self-concept and self-efficacy, which advocates the fact that students' perception about their ability is very critical to the educational success.

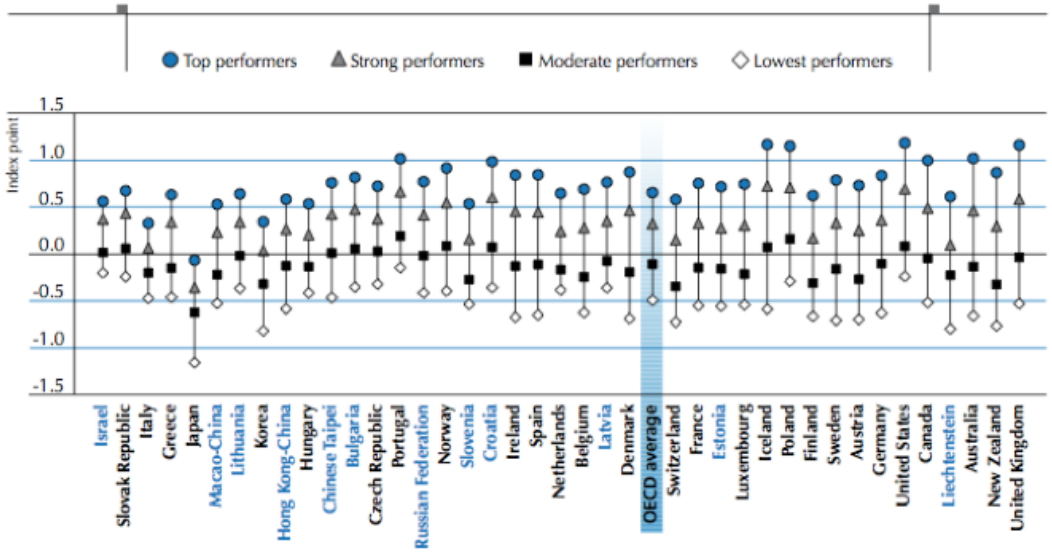


Figure 9: Self-Efficacy in Science, by Performance Group

2.5. System design principle to nurture top-performing students

Showing possible applications of concepts being taught in classes develops better understanding in the concepts for top-performing students whereas engaging lower-performing students in learning activities by providing freedom to investigate concepts and interact with other students can stimulate significant interest in scientific learning. As a consequence, it is suggested that learning activities at school should

provide possible real-world applications so they can appreciate concepts being taught in classes and then effectively apply those concepts in the future activities. Based on this finding, the first system design principle for learning systems is proposed and added to the list of system design guideline for nurturing more top performers at schools.

System Design Principle 1: Linking learning to real-world applications
Learning activities in a good learning system should link concepts being taught in the learning activities to real-world applications so learners can learn how to apply those concepts in reality if they are interested.

Table 3: System Design Principle 1

Regardless the socioeconomic status of students, the performance of top students strongly depends the level of enjoyment and interest in learning. As mentioned in the PISA report, 80% of top performing students enjoy learning science, are interested in learning science and have fun in learning. As a result, learning activities should be arranged in a way that students can enjoy and have fun with the learning activities instead of getting bored. This feature of a learning system should be appended into system design principles to help develop and cultivate characteristics of top-performing students.

System Design Principle 2: Enjoyment and Interest
Learning activities in a good learning system should be conducive to learner's enjoyment and interest.

Table 4: System Design Principle 2

Furthermore, students are more motivated to learn when they believe that they will definitely use the knowledge being taught in their desired jobs or future works.

According to the PISA report, 75% of top performing students feel motivated to learning science because they believe learning will help them in the work they want to do later. For this reason, the links between occupations and knowledge concepts used in occupational activities should be cognitively established and visualized to increase students' awareness. This possible feature of a learning system is also listed in the proposed system design principles.

System Design Principle 3: Bridging professional goals and concepts
A good learning system should show important connection between learner's desired professional goals (or roles in a society) and concepts being taught to the learner

Table 5: System Design Principle 3

As top-performing students have a great tendency to believe in their ability as well as confidence in accomplishing given academic assignments, a good learning system should empower students by building self-efficacy and self-concept over time. In order to instill characteristics of top-performing students, the following system design principle is included in the list of the learning system design guidelines.

System Design Principle 4: Self-Efficacy and Self-Concept
A good learning system must build and enrich self-efficacy (confidence in doing tasks) and self-concept (belief in own abilities) in student.

Table 6: System Design Principle 4

2.6. Finland as a Top Performing Country in Education

Finland is a country that has successfully transformed itself into a knowledge economy within a short time period despite a severe economic recession by a major

banking crisis, high unemployment rate (from 5% to 15%) and the accumulation of government debt (over 60% of GDP) in the early 1990s. By 2000, Finland has become one of the top performers in the international competitiveness rankings. With this magnificent turnaround, the Finnish education system, their innovation system and their research ecosystem are introduced in this section to fill in any missing system design principles.

2.6.1. Finland Education System

The Finnish education system is an egalitarian Nordic system where the tuition and meals are free for full-time students[14]. The education system requires students to attend the nine-year comprehensive school (home schooling is also allowed). During the first years of comprehensive school, grading may be limited to verbal assessment rather than formal grading. Then, the students can choose to continue three-year secondary education in either an academic track or a vocational track. While the tertiary education is divided into university and vocational university systems, only university system awards licentiate and doctorate degrees.

Education in Finland

<table>
<tr><th>Academic degrees</th><th colspan="2">Vocational degrees</th><th>Age</th></tr>
<tr><td>doctor</td><td colspan="2" rowspan="2">employment</td><td></td></tr>
<tr><td>licentiate</td><td></td></tr>
<tr><td>master</td><td colspan="2">Polytechnic(new)</td><td>+2-3</td></tr>
<tr><td>bachelor</td><td colspan="2">Polytechnic</td><td>+3-4</td></tr>
<tr><td colspan="2" rowspan="3">upper secondary school</td><td rowspan="3">vocational school</td><td>18-19</td></tr>
<tr><td>17</td></tr>
<tr><td>16</td></tr>
<tr><td colspan="3" rowspan="8">comprehensive school</td><td>15</td></tr>
<tr><td>14</td></tr>
<tr><td>13</td></tr>
<tr><td>12</td></tr>
<tr><td>11</td></tr>
<tr><td>10</td></tr>
<tr><td>9</td></tr>
<tr><td>8</td></tr>
<tr><td>7</td></tr>
<tr><td colspan="3">pre-school</td><td>6</td></tr>
</table>

Table 7: Education System in Finland

[14] Retrieve May 18, 2011 from http://en.wikipedia.org/wiki/Education_in_Finland

2.6.2. Finland Innovation System

The Finnish innovation system is accountable for this success. As shown in the figure 10, Parliament decides the total public resources to be allocated for innovation activities following on the research, technology and innovation policy developed by the Research and Innovation Council. The council is responsible for the strategic development and **coordination** of Finnish science and technology policy as well as the national innovation system as a whole[15]. Among the funding institutions, the Academy of Finland funds basic research while TEKES and SITRA fund applied research and development projects. SITRA is also considered a major think tank. Many Finnish policies enhance innovations through "direct R&D subsidies."

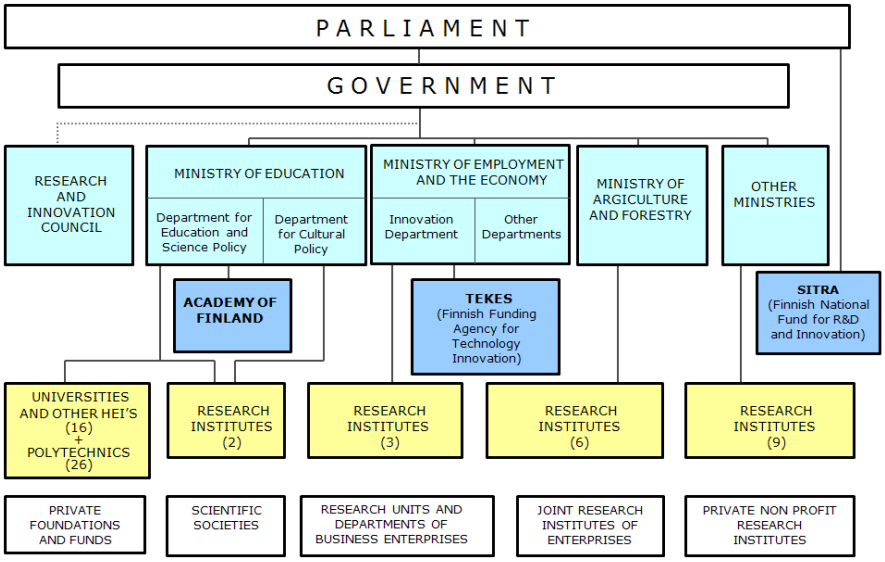


Figure 10: Finnish Innovation System

The coordination arranged by the Research and Innovation Council appears to be one of the keys to success of the Finnish innovation system when comparing to Thailand where insufficient coordination among numerous education-related government agencies in Thailand resulted in not only fragmented education efforts but

[15] Retrieve May 18, 2011 from http://cordis.europa.eu/erawatch/index.cfm?fuseaction=ri.content&topicID=35&countryCode=FI

also incongruous direction for overall education development. Rie Atagi[16], for example, found that no single government agency took responsibility for coordinating 11 different pilot projects related to learning reform, ICT in education, and the decentralization of educational administration and management. It is clear that the presence of a consistent development direction and a dedicated government agency is likely to help increase the success rate of education system improvement efforts.

2.6.3. Finland Innovation Environment

Another interesting characteristic of the Finnish innovation system is the intense stakeholder linkages in their innovation environment. For instance, a research entity can increase a chance of receiving R&D funding from TEKES when the R&D projects are performed in collaboration with other companies, research institutes and/or universities. No doubt that this approach promotes the collaborations and strengthen network among stakeholders in the Finnish innovation environment.

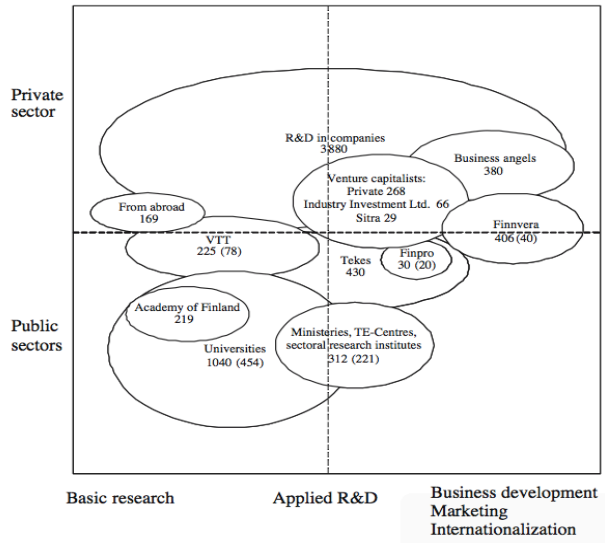


Figure 11: Finnish Innovation Environment: Resources and Funding[17]

[16] Fry, G. (2002). *The Evolution of Educational Reform in Thailand.* Retrieve May 18, 2011 from http://www.worldedreform.com/intercon2/fly.pdf

[17] Ylä-Anttila, P. & Palmberg, C. (2007). *Economic and Industrial Policy Transformations in Finland.* Journal of Industry, Competition and Trade 7(3), 169-187. Retrieve May 18, 2011 from http://www.springerlink.com/content/c054l28511075711/fulltext.pdf

The extensive R&D collaboration in Finland also supports the economic theory on research joint venture that research collaboration is likely to produce more R&D than research competition[18]. Players in both public and private sector in the Finnish innovation environment can be summarized in the figure 11.

2.7. System Design Principle Based on Finland Findings

The emphasis of coordination among key government agencies and organizations in both public and private sectors led Finland to become one of the top performing countries. Although developing educational policies are not considered within this thesis scope, a learning system could be designed to instill a sense of "teamwork" in learners through team-based learning activities. This learning strategy will cultivate learners with a value of collaboration and knowledge sharing, which are not only the shared value of Finnish students but also necessary for learners around the world in the era of globalization.

System Design Principle 5: Establish and Promote Coordination among Learners through Learning Activities
Learning activities in a good learning system should be assigned as team-based projects to instill a value of collaboration and knowledge sharing in learners.

Table 8: System Design Principle 5

[18] Dahlman, C., Routti, J. & Yla-Anttila, P. (2007, December). Finland as a Knowledge Economy: Elements of Success and Lessons Learned. World Bank Publications. Washington, DC.

3. Thailand Education System

3.1. Thailand Educational System Overview

The Thailand education system consists of 12-year groups (as known as grades). Typical students begin with pre-elementary school or kindergarten for about 3 years before transitioning to primary school for the next 6 years. After completing the primary school, they are expected to enter lower secondary school for 3 years to comply with the 9-year compulsory education. Then, they can choose continue to either upper secondary school or vocational and technical school[19]. Based on the National Curriculum 2008, there were eight core subjects, which are comprised of Thai language, mathematics, science, social studies, religion and culture, health and physical education, arts, careers and technology, and foreign languages (i.e., English mostly).

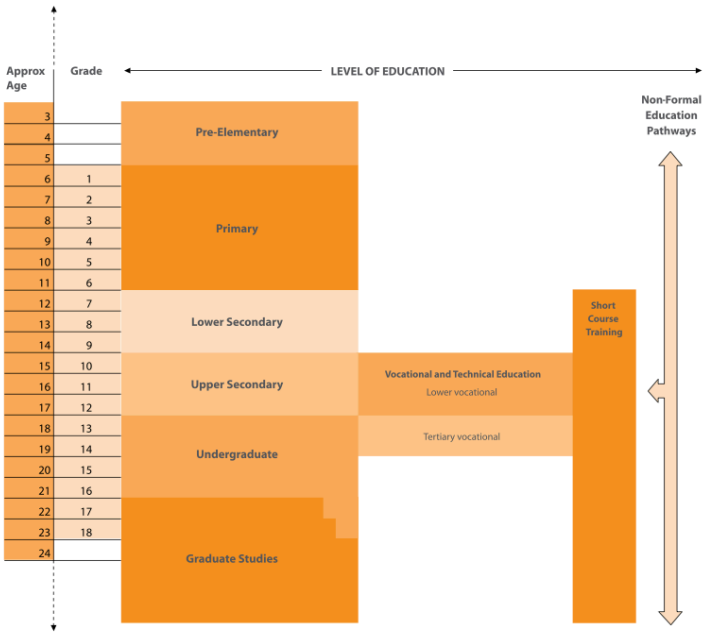


Figure 12: Thailand Education System

[19] Ministry of Education. (2008). *Towards A Learning Society in Thailand*. Retrieved on May 13, 2011 from http://www.bic.moe.go.th/fileadmin/BIC_Document/book/intro-ed08.pdf

3.2. Selected Statistic of Thailand Education System

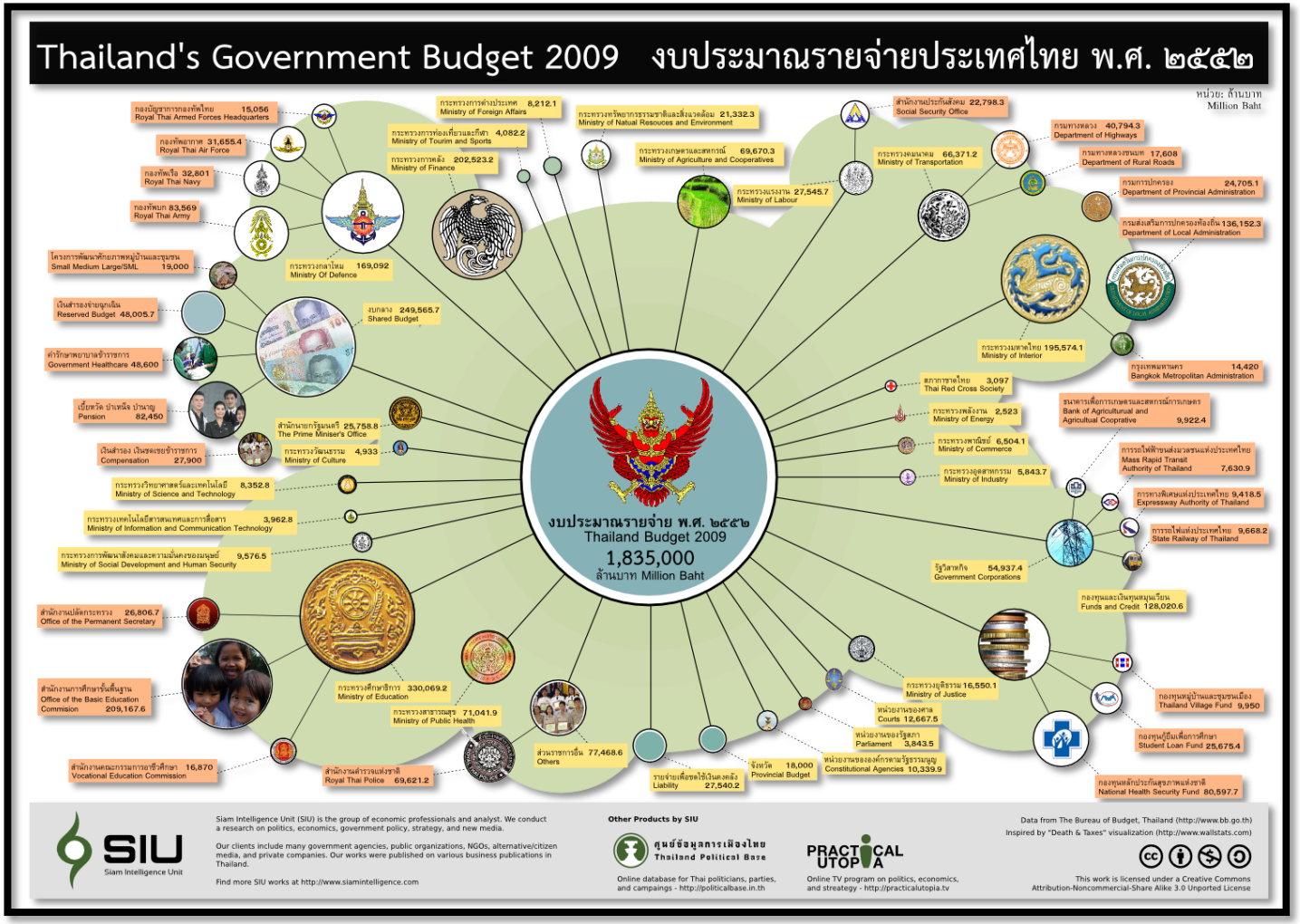


Figure 13: Thailand National Budget on Education

As shown in the figure 13[20], Thailand's government allocated about 18% of the national budget to Ministry of Education in 2009 while they spent 22.3% and 20.4% in 2010 and 2011 respectively (as shown in the table 14[21]). Moreover, 21.91% of national budget was allocated to Education in 2005.

(in million baht)

Education	FY 2010	FY 2011
1. Pre-Primary, Primary, and Secondary Education	282,212.1	310,330.0
2. Tertiary Education	62,604.2	71,749.8
3. Education not Definable by Level	2,052.8	2,406.2
4. Subsidiary Services to Education	22,471.5	22,747.4
5. Education not elsewhere classified	9,784.2	15,006.5
Total Education	**379,124.8**	**422,239.9**
Percentage of the Total Budget	**22.3**	**20.4**

Figure 14: Thailand National Budget on Education in 2010 and 2011

Although the national budget allocation for Education appears to consistently be the largest share of the national budget across sectors in the last 5 years, it is still questionable on whether those resources are equally and efficiently distributed among different income groups. Ms. Kohtbantau highlighted "the poorest 40 percent of the population receives 56 percent of total spending, reflecting a pro-poor allocation of resources. The distribution of resources for secondary level education is fairly equal; however, spending for tertiary education is clearly regressive. The wealthiest 20 percent of the population receives 53 percent of total spending.[22]" In addition, Atagi mentioned

[20] Retrieved on May 13, 2011 from http://siu.co.th/2009/02/visualization-of-thailand-budget-2009/
[21] BUREAU OF THE BUDGET. (2011). *THAILAND'S BUDGET IN BRIEF FISCAL YEAR 2011*. Retrieved on May 13, 2011 from http://www.bb.go.th/FILEROOM/CABBBIWEBFORM/DRAWER14/GENERAL/DATA0001/00001246.PDF
[22] Kohtbantau, A. & Fitts, P. (2006, October). *Thailand's Secondary Education System at a Crossroads: Despite Impressive Increases in Access to School, Challenges Remain.* Retrieved on May 13,2001 from http://www.worldbank.or.th/WBSITE/EXTERNAL/COUNTRIES/EASTASIAPACIFICEXT/THAILANDEXTN/0,,contentMDK:21085719~menuPK:333302~pagePK:2865066~piPK:2865079~theSitePK:333296,00.html

in her work that a large amount of budget for education was allocated to new buildings and land event though the budget could have spent on teacher development and educational researches[23].

To gain deeper insight into the characteristics of Education System in Thailand, some descriptive statistics[24] are summarized in the table below.

Indicator	Value	Global Ranking	Year
Education spending as percentage of total government expenditure	28.30%	2nd of 96	-
Education spending as percentage of GDP	5.20%	54th of 132	-
Public spending on education as percentage of total government expenditure	27.53%	4th of 103	2004
Public spending on education as percentage of GDP	4.23%	38th of 136	2004
Spending per primary school student	$1,048.00 per student	21st of 21	2001
Spending per secondary school student	$1,177.00 per student	21st of 21	2001
Education enrollment by level (Primary level)	6,112,687	3rd of 189	2003
Education enrollment by level (Primary level) per capita	0.097 per capita	6th of 172	2003
Education enrollment by level (Secondary level)	5,009,844	1st of 171	2003
Education enrollment by level (Secondary level) per capita	0.079 per capita	3rd of 159	2003
Education enrolment ratio, net (Primary level)	93%	3rd of 160	2006

[23] Fry, G. (2002). *The Evolution of Educational Reform in Thailand.* Retrieve May 13, 2011 from http://www.worldedreform.com/intercon2/fly.pdf

[24] Retrieved on May 14, 2011 from http://www.nationmaster.com/red/country/th-thailand/edu-education&all=1

Progression to secondary level	90.7	46th of 97	-
Schools connected to the Internet	37%	23rd of 39	2002

Table 9: Selected Descriptive Statistics of Thailand Education System

The table shows that most Thai students at least receive a formal education in both primary level and secondary level. However, since there were a large number of students with financial difficulties, the government spending per student was at $1,048 in the primary school level (while the weighted average is at $4,100.19 per student) and $1,177 in the secondary school level (while the weighted average is at $5,463.67 per student), which indicates that most education system resources (e.g., school, learning instruments, subsidized tuition) still heavily rely on the financial support from the government[25]. For this reason, the system architecture must be designed to help reduce education costs to allow students, especially with financial difficulties, to afford educational opportunities at their own will.

System Design Constraint 1: High Education Costs
A good learning system must be designed to help reduce education costs to allow students to afford educational opportunities at their own will.

Table 10: System Design Constraint 1

3.3. Unique Challenge In Thailand Education System

Other than a large proportion of under qualified teachers and an unequal access to high quality teachers like other developing countries, some traditional customs appear to a unique factor that discourages students to become an active and self-direct learner. For example, being considerate and respectful to teachers is one of the prevalent cultural norms in schools. If a student asks his teacher a

[25] Retrieved on May 13, 2011 from http://www.moc.moe.go.th/node/354

difficult question during a class and the teacher cannot answer it, this situation could make the teacher **lose face** and could be perceived as an insult. For that reason, students tend not to ask questions although they don't understand. This finding was also reported in studies in both Thai[26] and English[27].

Insufficient coordination among numerous education-related government agencies and English language literacy are other two challenges in Thailand education system. Although these two challenges will not be addressed within this thesis scope, it is important to explicitly state them in this section.

Insufficient coordination among numerous education-related government agencies results in not only fragmented education efforts but also incongruous direction for overall education development. Rie Atagi[28], for example, found that no single government agency took responsibility for coordinating 11 different pilot projects related to learning reform, ICT in education, and the decentralization of educational administration and management. The absence of a consistent development direction is likely to dilute education system improvement efforts, resulting little impact on Education.

Besides, limited English literacy separates non-English speaking students from the global knowledge system. Many Thai students don't have opportunities to learn English from native English speaker, resulting in the very low English proficiency when comparing with other ASEAN countries (shown in table 11).

[26] Retrieved on May 13, 2011 from http://www.moc.moe.go.th/node/354
[27] Hallinger, P. Kantamara, P. (2009). Paper prepared for the *Asia Pacific Journal of Education.* Retrieved on May 13, 2011 from http://www.philiphallinger.com/papers/APJE.pdf
[28] Fry, G. (2002). *The Evolution of Educational Reform in Thailand.* Retrieve May 13, 2011 from http://www.worldedreform.com/intercon2/fly.pdf

For this reason, it is challenging for Thailand knowledge system to interact with the other knowledge systems[29].

Country	Average TOEFL Scores	Rank
Cambodians	505	7
Indonesians	518	4
Laotians	496	9
Malaysians	527	3
Filipinos	578	2
Singaporeans	596	1
Thais	498	8
Vietnamese	511	6
Burmese	512	5

Table 11: TOEFL Mean Score of Students in ASEAN countries[30]

3.4. System Design Principle to mitigate identified challenges

Although both limited resources (i.e., numbers of unqualified teachers and unequal access to quality teachers) and some traditional customs in Thailand's classrooms can restrain students from nurturing active and self-direct learning mindset, the system architecture of intrinsically motivated learning systems can be designed to encourage students to take ownership of their own future success[31]. One approach is to promote the desire to be successful with

[29] Fry, G. (2002). *The Evolution of Educational Reform in Thailand.* Retrieve May 13, 2011 from http://www.worldedreform.com/intercon2/fly.pdf
[30] Prapphal, K. (2003). English proficiency of Thai Learners and Directions of English Teaching and Learning in Thailand. *Journal of English Studies 1*(1). 6-12.
[31] Project-Based Learning forces students to take ownership of their success – Wiki. Retrieved on May 13, 2011 from http://en.wikipedia.org/wiki/Project-based_learning

their favorite professions, which would not only shift learning responsibility to students but also instill the active and self-directed learning mindset in students.

System Design Principle 6: Promoting Ownership of Future
A good learning system should encourage students to take the ownership of their own future success.

Table 12: System Design Principle 6

3.5. Constructionist School in Thailand – DSIL Case Study

3.5.1. Background

Darunsikkhalai School for Innovative Learning (DSIL) was found in 2000 as a constructionist pilot school where the learning scheme is primarily based on the theory of constructionist learning (learning by making). The pilot school was one of the tangible assets led by the Lighthouse project[32] launched in 1997. At that time, a group of Thai industrialists, educators, and government officials approached Professor Seymour Papert and his group at the MIT Media Laboratory to help design and implement a radical change in Thailand educational system in order to develop learners for a knowledge-based economy. Constructing meaningful artifacts and projects were the core activities within the Lighthouse project to promote the development of both participating teachers and students. The Lighthouse project had demonstrated many extremely positive learning outcomes (e.g., increasing learning enjoyment, assimilating learners in computational learning environments, etc.), which inspire participating teachers to use this constructionist learning style at their

[32] Cavallo, D. (1998). Project Lighthouse in Thailand: Guiding Pathways to Powerful Learning. Retrieved on May 13, 2011 from http://el.media.mit.edu/logo-foundation/pubs/logoupdate/v7n1/v7n1-lighthouse.html

own schools. Unfortunately, there was a strong change resistance from their school managements to adopt the constructionist learning style because of their fixed mindset. For this reason, Khun Paron and a board member of the Suksapattana Foundation formed an idea of establishing a pilot school, resulting in the existence of Darunsikkhalai School for Innovative Learning (DSIL).

Figure 15: Darunsikhalai School of Innovative Learning (DSIL)

3.5.2. DSIL Learning Process

The theory of constructionist learning was used as an underlying principle to design the DSIL learning process, which consists of the following eight steps:

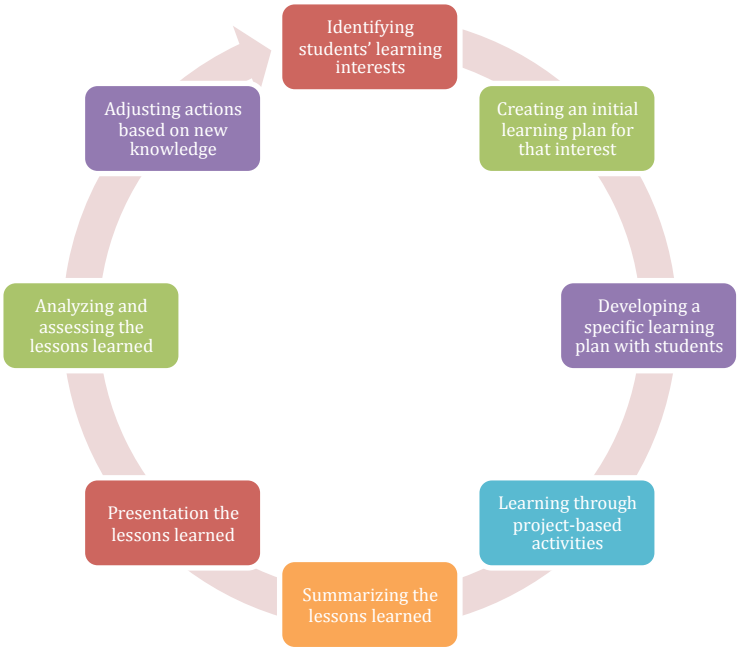


Figure 16: Darunsikhalai School for Innovative Learning Process

- A teacher stimulates and identifies students' learning interests in a class
- Teachers across fields (e.g., art, science, math) help create an initial learning plan for that particular interest
- The teacher develops a specific learning plan with students in the class
- Both teacher and students begin learning through project-based activities, for each activity both parties work together on: researching and planning; modeling and constructing; testing hypothesis and discussing with experts in the field; and exchanging Knowledge
- The teacher and students summarize the lessons learned
- The teacher and students present the lessons learned
- The teacher and students analyze and assess the lessons learned
- Students adjust actions based on new knowledge being constructed

3.5.3. DSIL Class Observation and Student Interviews

To gain better understanding of whether DSIL students actually benefit from the constructionist learning style, I visited DSIL and observed a couple of lectures in person. The experience gave me an impression that the constructionist learning style helped increase interactions between a teacher and students in classes, implying that students have higher interest and learning enjoyment in the learning activities, especially in subjects in science. It was interesting to note that students in primary and lower secondary school level were more enthusiastic in classes than in high school level. After discussing with DSIL high school students, they expressed that the constructionist learning style helped develop their "**systematic thinking skill**" but they perceived that DSIL students would not be able to compete on learning contents with those from

other leading schools where rote-learning style is used in the mastery of foundational knowledge. I presume at this point that rote-learning style could instill a large set of factual knowledge within a shorter time while the constructionist learning style develops "**learning skill**" that lasts for a lifetime. Based on a further discussion, most students planned to continue their study abroad so the Thai national standard test would not their big concern. When we discussed favorite learning activities, there was no consensus about their favorite and non-favorite learning activities. However, the common characteristics of their favorite ones were learning activities are "**fun and interesting"** while the common characteristics of their non-favorite ones are "**boring, routine and inappropriate to their perceived abilities (e.g., not too challenging, not too easy)."**

Since the teachers encourage students to develop their own social norms and choose their own learning topics, especially classes in science, some students commented that the limited number of DSIL students per grade year (i.e., about 20 students per grade year) as well as their diverse backgrounds impose a challenge of forming project-based groups in which the students shared the same learning interest.

3.6. Suburban School in Thailand – Kookhampittayasan School Case Study

Figure 17: Kookhampittayasan School in Khon Kean Province

During my research, Kookhampittayasan School[33] was introduced on a Thai television program because of its innovative learning method on Mathematics. To identify the differences between learners in an innovative school like DSIL and those in an innovative school in a suburban area, I arranged a trip from Bangkok to Khon Kean (a province in Thailand). The trip objective was to observe the actual learning environment and interactions between teachers and learners in a suburban high school in Thailand. It is important to note that Kookhampittayasan School is a typical school in Thailand suburban area but the school adopted the ”open-ended” learning approach as its learning scheme for Mathematics.

3.6.1. Kookhampittayasan School Learning Approach

The approach was originated in Japan in 1970s. Since 2002, Kookhampittayasan School has been using a so-called “open-ended” approach where students get engaged with a Mathematic open-ended problem. The open-ended problem is formulated in such a way that there are many correct but

[33] Retrieved on May 13, 2011 from http://www.kookhampittayasan.com/kookham.htm

incomplete answers. A class lecture usually takes about one hours. The students in a class are assigned in a team where each team can construct their own solutions for half hours, which sometimes introduce new ways of problem solving. Then, a teacher of the class let the students share what their solutions are to the rest of the class. At the end, the teacher provides the conclusion of the lecture.

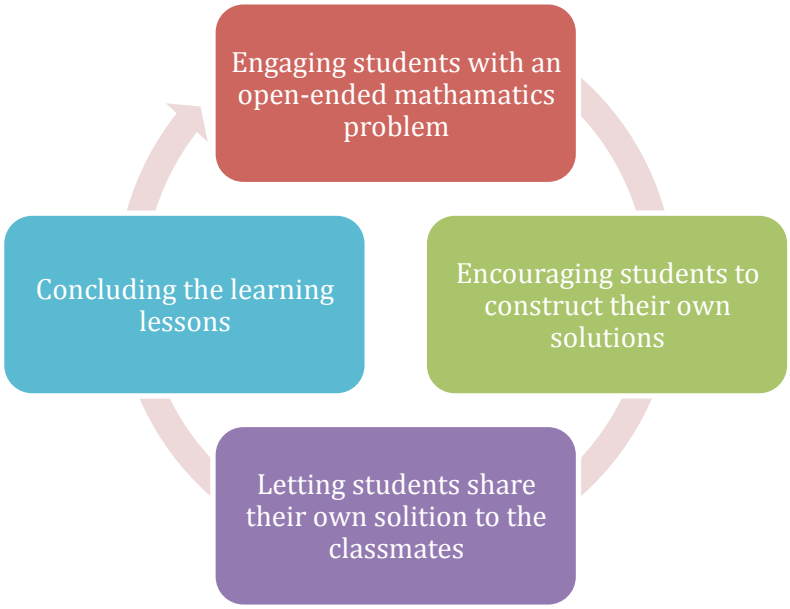


Figure 18: Kookhampittayasan School Learning Process

3.6.2. Class Observation and Student Interviews at Kookhampittayasan School

I arranged group discussions with students regarding favorite learning activities. I found that there is no consensus about their favorite learning activities. However, the common characteristics of their favorite ones were fun and appropriateness to their perceived abilities (e.g., not too challenging, not too easy). Interestingly, one learner in the focus group mentioned that "**working in a**

team" contributes to his desire to learn whereas another learner identified "**being omniscient**" as a drive to learn.

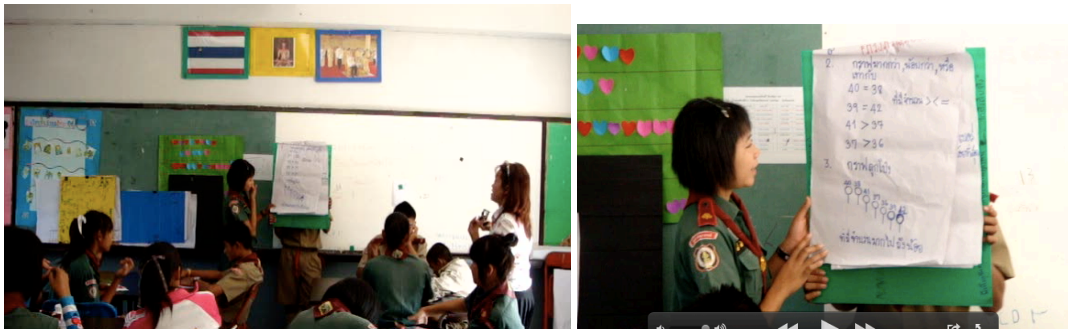


Figure 19: Kookhampittayasan School Class Observation

Although the current learning scheme can engage students more than the traditional rote-learning style, I noticed that a couple of students lost their attention from time to time because of the distractions from noises inside (i.e., chatting) and outside the classroom. My observations correspond to the research result[34] conducted to assess the "opened-ended" learning approach. The research results indicate that the students under this learning style perceived themselves as more active, more original and more hand-on experienced students. The students also expressed that the loud classrooms and unclear instructions were the dominant factors that retarded their learning experience.

3.7. System Design Principle through Case Study Analysis

The two cases of Thai schools obviously support that a good learning system strongly needs fun and interesting learning activities, which has already been proposed in our list of system design principles (number 2). Beyond fun and interesting, the learning activities must be appropriate for their perceived competence level. Working as a project team, in which students shared similar

[34] Inprasitha, M.. (2006). Tsukuba Journal of Educational Study in Mathematics (25). Retrieve on May 13, 2011 from http://www.human.tsukuba.ac.jp/~mathedu/journal/vol25/inprasitha.pdf

interest and competence level, also shows a tendency to promote "fun" in the learning activities. The analysis of these two cases led to the proposed system design principle number 7.

System Design Principle 7: Forming a Homogeneous Team
Learning activities in a good learning system should be assigned to teams in which team members shared similar leaning interest and competence level.

Table 13: System Design Principle 7

4. Revolutionary Learning Theory

Even though the common characteristics of successful education systems and educational challenges in developing countries like Thailand can offer an overview of currently desired learning system features, it is vital to review revolutionary ideas in "learning" to gather key concepts used to synthesize core design principles for the architecture of future learning systems.

There are four orientations to learning summarized in the table 14[35]. Since the thesis objective is to develop system architecture of learning systems that not only instill an active and self-directed learning mindset into learners but also develops learning skills for the learners, only literature in the aspect of cognitive learning theory (i.e., Piaget and Papert) and humanistic learning theory (i.e., Maslow) become the main focus at this point.

Aspect	Behavioral	**Cognitive**	**Humanistic**	Social and situational
Learning theorists	Thorndike, Pavlov, Watson, Guthrie, Hull, Tolman, Skinner	Koffka, Kohler, Lewin, Piaget, Ausubel, Bruner, Gagne	Maslow, Rogers	Bandura, Lave and Wenger, Salomon
View of the learning process	Change in behavior	Internal mental process (including insight, information processing, memory, perception	A personal act to fulfill potential.	Interaction /observation in social contexts. Movement from the periphery to the centre of a community of practice
Locus of learning	Stimuli in external environment	Internal cognitive structuring	Affective and cognitive needs	Learning is in relationship between people and environment.
Purpose in	Produce behavioral	**Develop capacity and**	**Become self-actualized,**	Full participation in communities of practice

[35] Smith, M. K. (1999). *'Learning theory', the encyclopedia of informal education*. Retrieve May 20, 2011 from www.infed.org/biblio/b-learn.htm

education	change in desired direction	**skills to learn better**	**autonomous**	and utilization of resources
Educator's role	Arranges environment to elicit desired response	Structures content of learning activity	Facilitates development of the whole person	Works to establish communities of practice in which conversation and participation can occur.

Table 14: Comparison of Learning Orientations

While the literature in the aspect of cognitive learning theory is introduced in this chapter, the literature in the aspect of humanistic learning theory is saved for the next chapter. This chapter begins with the concept of lifelong learning, which appears necessary for all individuals in the 21st century. Then, the concept of constructivism, constructionism and cultural-history psychology are presented respectively.

4.1. Lifelong Learning

The concept of the lifelong learning is introduced to present the radical change in perspectives on education during last few decades. Due to rapid change in all aspects globally, the competition in both business and non-business landscape becomes fiercer. This phenomenon not only tremendously transforms the definition of the "education" over time but also originates a new mindset of lifelong learning. This new mindset is now indispensible for any individual seeking life improvement as well as smarter living. Before this concept was introduced, people used to think that education was limited by learning activities occurring within student life at schools. The belief about the traditional definition of education is far from today's truth, when learning activities actually occur across the whole life span. Frequently, the difference in forms and environments unconsciously influenced the learners' perceptions, resulting in

the distorted definition of education. For that reason, a clear definition of education in the perspective of lifelong learning is introduced in the next section.

4.1.1. Definition of Lifelong Learning

There have been a number of controversial discussions to define the precise meaning of the words "lifelong learning". Although several different approaches are invented to conceptualize this particular terminology, the meaning varies in different contexts. Nevertheless, there are at least four functions of the notion of lifelong education[36]:

- The preparation of individuals for the management of their adult lives
- The distribution of education throughout an individual's lifespan
- The educational function of the whole of one's life experience
- The identification of education with the whole of life

Based on the functions above, a simple and concise description of the lifelong learning concept developed specifically for this thesis scope is:

The Thesis's Definition of Lifelong Learning
"A state of the learners' mindset where the learning behavior has already changed from passively absorbing knowledge from subject matter experts or routine circumstances to actively seeking for new activities contributing to learners' new skills and knowledge while improving competency of possessed skills throughout the whole lifespan."

Table 15: Thesis's Definition of Lifelong Learning

[36] Aspin, D. & Chapman, J. (2007). Philosophical Perspectives on Lifelong Learning. Lifelong Learning Book Series 11, 19-38. Springer Netherlands. Retrieved on May 15, 2011 from http://www.springerlink.com/content/v32786303p48262w/

This description is very close to the definition specified in David Aspin's paper stating that lifelong learning is concerned with promoting skills and competences necessary for developing general capabilities and specific performance in work situations. In order to demonstrate the distinction between a traditional concept of the school and the lifelong learning, a comparison table from Gerhard's paper[37] is excerpted below.

	School / University	Lifelong Learning
Emphasis	"Basic" skills; exposure; access	Education embedded in ongoing work activities; informed participation
Potential Drawbacks	Decontextualized, not situated	Important concepts are not encountered
Problems	Given	Constructed
New Topics	Defined by curricula	Arise incidentally form work and situations
Structure	Pedagogic or "Logical" Structure	Work activity
Roles	Expert-Novice Model	Reciprocal learning; "Symmetry of ignorance"
Teachers/ Coaches	Expound Subject Matter	Engage in work practice
Mode	Instructionism (knowledge absorption)	Constructionism (Knowledge construction)

Table 16: Comparison of Different Conceptualization of School and Lifelong Learning

As lifelong learning can be presented in various forms, the next section provides some common forms that are based on the described characteristics in the comparison table.

[37] Fischer, G. (1999). Lifelong Learning: Changing Mindsets. Retrieved May 15, 2011 from http://www.cs.colorado.edu/~gerhard/papers/icce99.pdf

4.1.2. New Forms of Learning in Perspective of Lifelong Learning

Learning in the information age occurs in various interactive forms and locations (i.e., conversation on the phone, discussions in the virtual meeting room and so on) where each individual learner constructs the learning objective on their own and develop a choice of possible learning plans to solve the defined problem. According to Gerhard, the new forms of learning consist of:

- **Self-directed learning:** This form of learning gives a full control to students to define their own leaning objective. The knowledge is constructed when the learners formulate a problem that they are motivated to solve and then develop a research plan with peers or even teachers through conversations to ensure the validity of the plan. Furthermore, the importance of this form of learning was also highlighted in the research paper[38], from the Schiefelbusch Institute for Life Span Studies, which indicates "skills associated with becoming more self-determined (e.g., setting goals, problem-solving, decision-making, self-management) are important for a successful transition from school to adult life." Once the learners acquire these skills, he is able to handle all the challenges in their lives better. Conversely, this type of learning form could impose a new risk to the learners if they don't understand their own needs or lack motivation to learn.

[38] Retrieve May 15,2011 from http://www.beachcenter.org/research/FullArticles/PDF/SD9_Promoting%20Transition%20Goals%20and%20Self-Determination.pdf

- **Learning on Demand:** Since change is constant, it is unavoidable for the learners to assimilate new knowledge when a given task requires that particular knowledge. We observe that this form of learning is actually prevalent in many of our life activities. For example, if the learner is assigned to repair a computer, he first needs to understand how the computer works. This learning form demonstrates the necessity of the fundamental learning skill. Consequently, the development of learning skill appears more important than the understanding of the knowledge.
- **Informal Learning:** Learning is not restricted to the formal educational institutions. Instead, the learning is moving from school and libraries toward home, community and workplace where the daily interactions and shared relationships among members are the primary means of learning.
- **Collaborative and organizational learning:** When there are collaborative interactions among learners, not only are the dissimilar ideas discussed among learners through socialization, leading to a new knowledge and innovative idea, but also shared beliefs and values are unconsciously exchanged. One evident example is discussion in a brainstorming session among learners. The most agreeable idea is chosen and supported by that group of learners of whether the idea is the best.

4.1.3. System Design Principles to Support Lifelong Learning

As the shift in mindset from 'school' to lifelong learning is transforming every knowledge society, a good learning system must be designed to support the vision of lifelong learning. Not only should a good learning system support learners to learn continuously following self-directed learning objectives but also cultivate the appropriate personal beliefs and habits to always seek learning opportunities to improve their own skills. For this reason, two design principles are initially proposed below as the learning system guidelines to support lifelong learning.

System Design Principle 8: Supporting Lifelong Learning
At a given time, a good learning system must help the learners to not only define their desired learning objectives but also define the learning space in alignment with the defined learning objectives.

Table 17: System Design Principle 8

Since there are many things a person can learn during a lifetime, a good learning system should empower learners to articulate their most preferred learning focus at a time. According to the study conducted in 2001 by Joshua Rubinstein, Jeffrey Evans and David Meyer, the research team found that people lost significant amounts of time as they switched among multiple tasks. This finding confirms that although people can work on several things in parallel, it is difficult to focus on several things at the same time due to the natural limits of

human cognitive ability. Also, a good learning system must assist learners in confining the learning space according to the selected learning focus.

System Design Principle 9: Personalized Learning Plan
A good learning system must encourage the learners to develop a personalized learning plan, which includes defined learning goals and objectives.

Table 18: System Design Principle 9

In order to fulfill a learning objective, key learning goals must be listed. This will allow the learners to develop a strategic learning plan to systematically achieve the defined learning goals and then fulfill the learning objective. For that reason, the learning plan is very critical to the learning success at the end. In accordance with the research paper[39] from Schiefelbusch Institute for Life Span Studies, almost all the students who learned how to develop their learning plan through a Self-Determined Learning Model of Instruction dramatically improve their learning performance. The evidence shows that a good learning system must have this system feature to help learners succeed in learning regardless of learning activities.

4.2. Constructivism Theory

When considering a famous revolutionary perspective attempting to address an ambitious but mysterious question about learning, such as "How do we come to know?" in recent decades, most researchers and educators would think of Piaget's assertion as the starting point. Piaget, who is a Swiss

[39] Retrieve May 15, 2011 from http://www.beachcenter.org/research/FullArticles/PDF/SD9_Promoting%20Transition%20Goals%20and%20Self-Determination.pdf

developmental psychologist, stated that the knowledge was not a simply direct copy of reality. Instead, knowledge is acquired and constructed through a constructivist process where an individual organizes, structures and restructures experiences in accordance with the existing objects accumulated inside his/her mental model[40].

Piaget's primary assumption is one of subject-object unity, describing the discovery that knowledge does not simply come from the object or the subject but the interaction between the subject and the perceived object. To understand an object in reality, a learner must interact and transform the perceived object. For example, a learner may connect, displace, combine, take apart, reassemble or do all together in his own way to construct a new meaningful object, resulting in the new knowledge about the perceived object. However, the new knowledge is not a copy of reality. It is just only a chosen part of the object a learner may select. Piaget further assumed that there are two types of activities to construct such knowledge. The first type is the coordination of actions while the second type is the coordination related to the object. Each activity type also constructs a different type of knowledge. The coordination related to the object constructs physical knowledge, which relates to the figurative aspect of the object because the subject tries to represent the object without transforming it. In contrast, the logical mathematical knowledge is derived from the learner's reflection on his own coordinating activities.

[40] Siegel, I., Brodzinsky, D. & Golinkoff, R. (1981). New directions in Piagetian theory and practices. Hillsdale, NJ. Lewrence Erlbaum Assiciates, Inc.

4.3. Constructionism Theory

The term "constructionism" is firstly coined by Professor Seymour Papert to describe the notion that knowledge is effectively constructed inside the mind of learners when the learners make their own "objects-to-think-with" tangible and sharable with others. While making the objects tangible encourages learners to externalize their internal ideas in concrete forms, making the objects sharable helps other learners not only transform and build upon those ideas but also co-construct new knowledge together. Although Papert and Piaget share the same view that anything is easy to learn if learners can assimilate that matter to the existing collection of models in their minds, Papert went beyond the cognitive aspect of the Piaget's original theory by including the dimension of affection. With positive affection toward some particular "objects-to-think-with", learners can easily recall and use those existing mental models to construct more complex knowledge. For example, Papert's favorite mental models were gears. Papert once mentioned about his affection toward gears in his childhood experience:

"*Playing with gears became a favorite pastime. I loved rotating circular objects against one another in gear like motions and, naturally, my first erector set project was a crude gear system."* So, when he got into an elementary school, the gears served as models for him to assimilate new knowledge. "*I saw multiplication tables as gears*[41]," he thought.

His personal story showed that he used a mental gear model to construct new concepts based on his existing concept of gears, which is more concrete than a multiplication table. Since a computer is versatile and flexible enough to be transformed into a thousand of different forms that serve numerous functions,

[41] Papert, S. (1980). Mind-storms Children, Computers, and Powerful Ideas. Basic Books, Inc.

Papert believes that the computers are the best learning instruments for all learners to construct their own "objects-to-think-with" like the gears were for Papert. It is important to note that the focus is not the "objects-to-think-with" constructed by the computers but the learner's mental models constructed for a lifetime through the experience of making the "objects-to-think-with". Once the mental models are constructed, learners can think on their own even when the physical contact with a computer (and objects-to-think-with) is removed. Thanks to Papert's theory, education researchers in last few decades focus more on creating the learning conditions where the learners can develop personal affection on "objects-to-think-with", resulting in more learning enjoyment.

4.4. Cultural-Historical Theory

Vygotsky is a Russian psychologist who invented the cultural-historical theory, explaining that the development of a child's cognition is the result of his or her interactions with others within a specific social context. He also believes that the culture where a child has been immersed influences the cognition of the child. Specifically, the way a child thinks, remembers, listens, communicates and solves a problem appears to depend on the social context. Furthermore, he conceived that a human mind was constituted of human history (phylogeny) and a person's individual history (ontogeny). Therefore, his notion of a children development is often referred to as the "cultural-historical theory"[42]

4.4.1. The Vygotskian Framework

Vygotsky proposed four basic principles to child development known as Vygotskian Framework, which comprise:

[42] Bodrova, E. & Leong D. (2007). Tool of the mind: the Vygotskian approach to early childhood education (9-11). Upper Saddle River, NJ. Pearson Education, Inc.

1. **Children construct knowledge**

Although Vygotsky shared the same view with Piaget on the belief that children construct their own understandings, Vygotsky focuses more on the influence of present and past social interactions while Piaget seemed to be more interested in interactions with physical objects. Vygotsky also believes that physical manipulation and social interaction are necessary for development. For that reason, teachers' will be the key to mediate how children should learn; as teachers act as a filter to select which ideas the children will learn.

2. **Development cannot be separated from its social context**

According to Vygotsky's work, the social context is more important to children development than pure attitudes and beliefs since the social context is a part of development process as well as a part of molding children's cognitive processes. The social context can be considered at several levels:

- **Immediate interactive level –** the direct interaction between a child and another individual at the moment. For example, a child whose mother emphasizes learning the names of objects will think differently from a child whose mother lets him/her play on his/her own.
- **Structural level –** the social structure such as family and school can also influence a child. Children raised in orphanage did not have the same level of planning and self-regulatory skills compared to children raised in families.

- **General culture or social level –** the features of society at large, such as language, numerical systems, and the use of technology can impact children's development as well. For instance, Asian children who used an abacus had different concepts of numbers than those who did not.

Westerners are accustomed to viewing cognition as a set of internal mental processes for an individual. However, there are many growing number of studies that regard the concept of cognition as a shared process recognize the importance of social context in this mental process acquisition. For that reason, children tend to learn and acquire a mental process by sharing, or using it when interacting with others. This discovery emphasizes the importance of social culture in all levels, which is the key to defining a model for how children discover not only what to know but also how to think.

3. Learning can lead development

Unlike behaviorists, Vygotsky argues that learning and development are different processes. He believes that although maturational prerequisites are needed for some specific cognitive development, learning can hasten and even causes the cognitive development, which contradicts the beliefs of some theorists who postulate that the maturation must exist before major development processes can occur. For example, a 3-year old girl is classifying objects but she cannot keep them straight. Her teacher gave her two boxes, each of which contains a word and a picture to assist her in keep the object straight. As a result, the girl can categorize other objects as well as learning the word and image, which hasten the development of categorical thinking. This example

shows that the learning can lead development if there is a proper learning context setup.

4. **Language plays a central role in mental development**

Since the language is a main mechanism used to describe an abstract concept or idea without the actual object present, language allows children to imagine, manipulate and share ideas with others. Since shared activity is the means that facilitates a child's internalization of mental processes, children's cognitive processes will be constructed and developed further as a result of dialogues and discussions.

4.4.2. Key Vogotskian Strategies for Development and Learning

Zone of Proximal Development (ZPD) is one of the best known of Vygotsky's concepts whereby Vygotsky believes that there are two levels of behavior development or skill development[43]:

- The lower level where a learner can solve a problem independently
- The higher level where a learner still needs both direct guidance or indirect help (i.e., facilitate learning, setup environment) from more capable mentors to assist in solving a problem or in performing

As Vygotsky conceived development as a continuum of behaviors, not as a discrete scale, he chose the word "zone" to describe the wide range of skills or behaviors that could be develop in near future while "proximal" emphasizes that

[43] Bodrova, E. & Leong D. (2007). Tool of the mind: the Vygotskian approach to early childhood education (P.86). Upper Saddle River, NJ. Pearson Education, Inc.

only some behaviors or skills closely associated to the learning activities will be developed, not all within the zone.

The size of ZPD is dynamic for each student and varies from person to person. Some students might need little help or time to make leaps while the others might need significant assistance and time to accomplish just a small lesson. Also, a student could have different ZPD sizes at different times in the learning process. For example, the student does not have trouble acquire reading comprehension but has a great difficulty in long division. Moreover, Vygotsky depicted the ZPD as shifts when the child attains a higher level of thinking and knowledge, so the development can be illustrated as a sequence of dynamic zones, which have their own unique sizes.

Recently, the National Association for the Education of Young Children published the Basic of Developmentally Appropriate Practice (DAP), which took the idea of ZPD into account. Copple and Bredekamp[44] encourage teachers to meet learners "where they are, taking into account their physical, emotional, social and cognitive development and characteristics" but at the same time to "identify goals for children that are both challenging and achievable." In other word, the teacher must identify the independent level (lower level) of performance and goals that are beyond the independent level but are still achievable in the ZPD zone. By observing children's reactions, teachers can assess whether the learning activity that is designed to develop skills is still in ZPD or not. If a child accepts the teacher's support, the activity is in ZPD. If the child ignore, fail to use or incorrectly use the skill, these feedbacks mean that the

[44] Bodrova, E. & Leong D. (2007). Tool of the mind: the Vygotskian approach to early childhood education (P.45). Upper Saddle River, NJ. Pearson Education, Inc.

learning activities are outside the ZPD zones. Vygotsky also emphasizes that the child should practice what he can do on his own while being exposed to elements at the higher levels of the ZPD.

Shared Activity is the second concept where Vygotsky believes that the mental functions can be shared in learning activities where the learners stay mentally active. The activities need a medium to encourage sharing. Although the novice-expert interactions seem to be a traditional type of shared activities that was believed to significantly promote learning, learner's peers and partners also contribute to learning.

4.4.3. System Design Principle Based on Vygotskian Framework

Since Vygotsky has not clearly explained how to reach the upper limit of the ZPD zone, several researchers have tried to develop more specific ideas to fill the missing gap. Scaffolding is one idea proposed. Basically, they recommended experts should "reduce or simplify steps required to solve the problem so the child can manage them, maintain the child's interest in pursuing the goal, point out the critical features that show the difference between the child's performance and the ideal performance, control frustration, and demonstrate the idealized version of what the child is doing."

Based on their recommendation and Vygotsky ZPD concept, one more principle is added to the learning system design principles proposed earlier to support learners in learning and development in Vygotskian style.

System Design Principle 10: Zone of Proximal Development (ZPD)
A good learning system should not only assess the current level of each individual learner's capability, noting where the learner can solve problems without assistance. The system should concurrently introduce a set of appropriate bite-size learning activities within the ZPD, designed to enable each learner to reach the upper level of the ZPD.

Table 19: System Design Principle 10

A learning activity is an instrument for learners to not only help students to assess their current level of understanding about some specific concepts/ideas but also encourage them to learn about new concepts or ideas they have not yet acquired. To qualify Vygotsky's definition of what constitutes a learning activity, the next section is provided.

4.4.4. Learning activity

A learning activity can be defined as a child-initiated activity driven by enquiry motivation (intellectual curiosity). Vygotsky suggested that a good learning activity must have the following components:

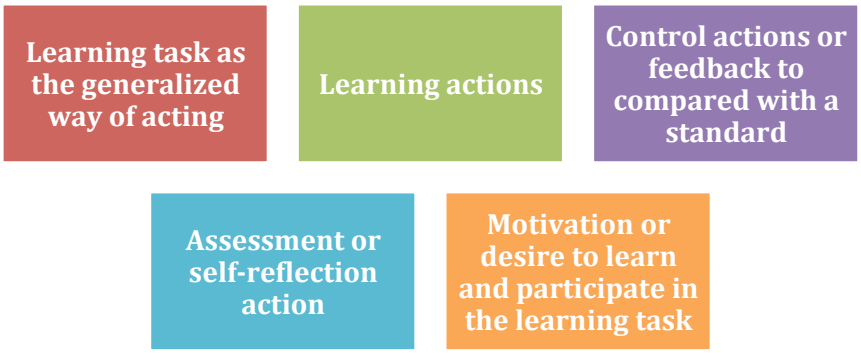


Figure 20: Learning Activity Components

- **Learning task as the generalized way of acting**

  The goal of a learning activity is not to acquire facts but to discover general principles explaining those facts.

- **Learning actions**

  Each learning action appears in a sequential, explicit form where the learner proceeds in a step-by-step fashion. Mediators could be also used to make those steps more discernable.

- **Control actions or feedback to compared with a standard**

  The learning activity must have a feedback mechanism to ensure the accuracy of the learner's comprehension as well as to facilitate comparison of the learner's performance with the standard or benchmark.

- **Assessment or self-reflection action**

  Learners must become aware of what they can do as a result of having participated in the activity that they could not do before.

- **Motivation or desire to learn and participate in the learning task**

  Learner must see the learning activity as something worthy of learning, interesting and useful.

5. Motivation Theory

This chapter is dedicated to introduce selective theories in the field of motivation in order to illuminate how motivation originates inside an individual's mind. The comprehension of this internal dynamic is the only way to reveal an effective design of the conceptual learning system that can intrinsically motivate humans to learn. Not only can knowledge in this particular science shed light on how such a system should be designed to well serve its main purpose but also provide insights on to motivation to help prescribe a set of system design principles grounding this unique conceptual learning system.

Whilst historical studies in psychology suggested that biological needs is an important contributing factor driving humans to perform a task, modern studies reveal two additional types of motivation which are:

- **Intrinsic motivation** – the motivation that is driven by an individual interest, enjoyment and satisfaction in a task
- **Extrinsic motivation** – the motivation that is driven by external factors where their forms appear in both tangible and intangible rewards such as money, prizes, compliment or even punishments and competition.[45]

Unlike extrinsic motivation that often directs human's attention to the outcome of an activity rather than the joy of experiencing such the activity, intrinsic motivation appears to be the most important source of psychic energy that not only sustains but also promotes lifelong human learning and development because intrinsic motivation usually establishes some kinds of

[45] Retrieved May 15, 2011 from http://en.wikipedia.org/wiki/Motivation

affective connections between a learner and a learning activity, resulting in more enjoyable learning experience, more curiosity to explore, more energy to master, and stronger activity engagement. According to a number of experts in this field, the natural inclination toward intrinsically motivated behavior also plays an important role in development, high quality performance and well-being[46]. For that reason, this chapter focuses more on the works of intrinsic motivation rather than extrinsic motivation.

This chapter begins with basic concepts and fundamental theories in motivation field to provide readers a basic understanding for advanced theories and sophisticated frameworks. Then, the meta-analytical results of the effects of dissimilar types of rewards is presented in the following section to unveil some unprecedented rewarding techniques that could be used to build and stem intrinsic motivation within an individual's mind. Next, two compelling process models of intrinsic motivation are introduced to illustrate how the intrinsic motivation might be internally created. Along the way to the end of this chapter, the new set of system design principles synthesized from the discovered knowledge in motivation domain are incorporated into the existing list of the learning system design principles to become a more comprehensive list.

5.1. Fundamental Theories in Motivation

5.1.1. Maslow's Hierarchy of Needs

In 1943, Abraham Maslow's paper "A Theory of Human Motivation" was published in Psychological Review to propose his framework of human

[46] Sansone, C. & Harackiewicz, J. (2000). Intrinsic and Extrinsic Motivation: The Search for Optimal Motivation and Performance (P.17). Orlando, FL: Academic Press.

motivation. The main idea of this theory is that humans are motivated by unsatisfied needs, which are classified into five layers where he called "deficiency needs". The fundamental layer of the deficiency needs is physiological needs, followed by safety needs, love and belonging, esteem and self-actualization. Also, certain elements in a lower level need to be satisfied before humans can be motivated by other elements in a higher level.

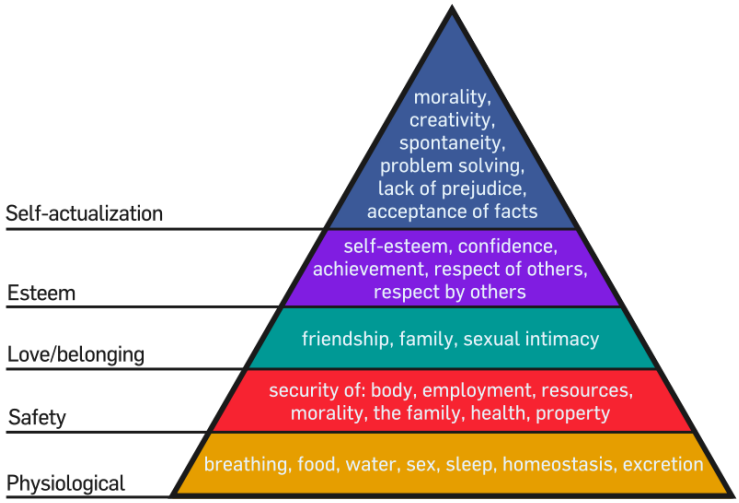


Figure 21: Maslow's Hierarchy of Needs[47]

- **Physiological needs** are the literal requirements for human survival such as air, food and water. It is obvious that if these requirements are not fulfilled, human body will no longer function, resulting strong motivation to fulfill these needs.
- **Safety needs** are the needs of being free from physical threats and emotional harms, which includes but not limited to personal security, financial security and health and well-being.
- **Love and Belonging** indicates the needs for social connections and social acceptance obtained from both large social groups (e.g., professional

[47] Retrieved May 15, 2011 from http://en.wikipedia.org/wiki/File:Maslow%27s_Hierarchy_of_Needs.svg

organizations, religious groups) and small groups (e.g., family members, mentor, friends).

- **Esteem** is the needs for the respect of others (lower level) and self-respect (higher level). So, people are motivated to be engaged in activities in order to feel accepted and self-valued.
- **Self-Actualization** is the desire to reach one's full potential as a person. Motivators in this category are truth, justice, wisdom and the likes.

Although Maslow's Hierarchy of Needs can provide an interesting explanation of how human motivation originates in the first place, other theorists believe that this theory can still be improved, leading to the invention of the ERG theory of motivation.

5.1.2. ERG Theory of Motivation

Since the theory of Maslow's Hierarchy of Needs cannot clearly explain some behaviors such as a starving artist who is willing to value growth needs rather than existence needs, Clayton Alderfer revised and simplified Abraham Maslow's Hierarchy of Needs and introduced his ERG Theory in an article titled "An Empirical Test of a New Theory of Human Need" in Psychological Review in 1969. The ERG theory consists of three categories, which are:

- **Existence –** corresponds to the physiological and safety needs combined
- **Relatedness –** is analogous to social and **external** esteem together
- **Growth –** is the needs for **internal** esteem and self-actualization

The needs of ERG theory can be mapped to those of Maslow's theory as shown in the figure below.

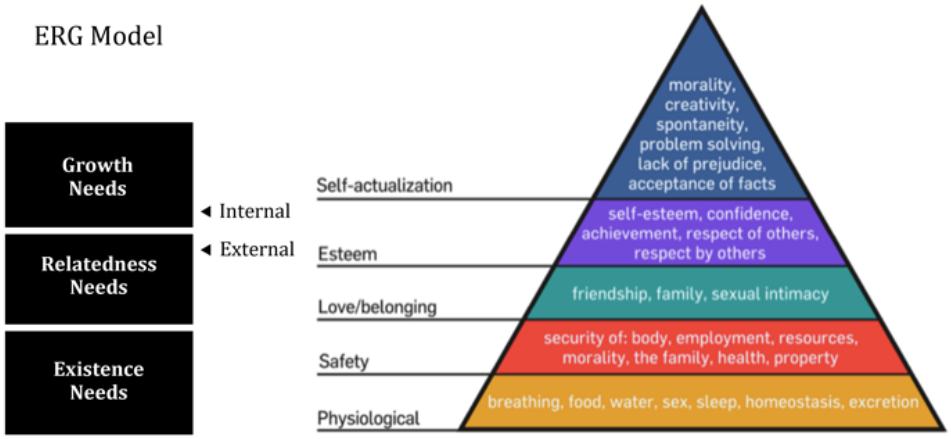


Figure 22: Needs of Maslow's Theory mapped to ERG Theory

Unlike Maslow, Clayton views these needs as a continuum not a hierarchy, which allows not only these needs to be simultaneously pursued but also the order of the needs to be different for dissimilar individuals. As shown in the diagram above, if a higher level of needs is unfulfilled, a person may regress to a lower level of needs that appear easier to satisfy. This behavioral outcome is known as frustration-regression principle.

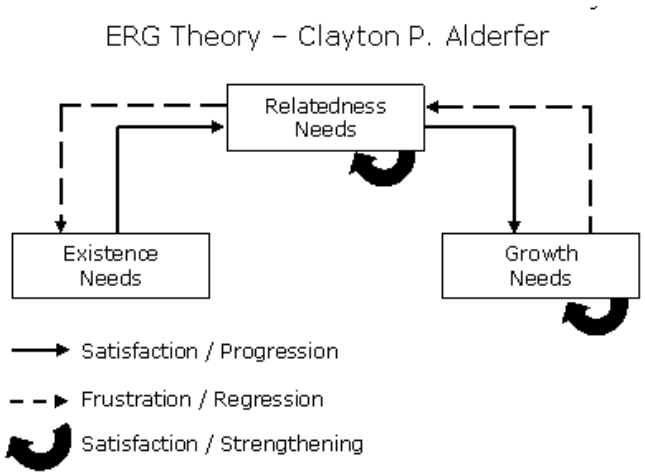


Figure 23: ERG Theory Diagram[48]

[48] Retrieved May 15, 2011 from http://downloadsoftwarestore.com/software_images/20/52/00045220/ERG_Theory__MBA_-screenshot.gif

Although the ERG theory and the theory of Maslow's Hierarchy of Needs suggest a simple systematic framework that empowers us to anticipate what kinds of behaviors could be expected from an individual at a given state, these frameworks offered only an overview how intrinsic motivation might be created and developed inside an individual's mind. Thanks to Edward Deci and Richard Ryan, more sophisticated framework addressing how intrinsic motivation originates was studied, resulting in the **Self-determination Theory (SDT).**

5.1.3. Self-Determination Theory (SDT)[49]

According to the website of the Department of Clinical and Social Sciences in Psychology at the University of Rochester[50], this theory assumes that "people are active organisms, with evolved tendencies toward growing, mastering ambient challenges, and integrating new experiences into a coherent sense of self." The SDT suggested that the healthy development and functioning require three innate psychological needs, which are:

- **Competence** – Ability to effectively deal with ambient challenges
- **Relatedness** – A universal want to interact, connect and experience caring for others
- **Autonomy** – Ability to control of actions in harmony with an integrated self

[49] Retrieved May 15, 2011 from http://changingminds.org/explanations/theories/cognitive_evaluation.htm
[50] Retrieved May 15, 2011 from http://www.psych.rochester.edu/SDT/index.php

If these three innate needs are fulfilled, the optimal function and growth will likely take place. SDT consists of five mini-theories[51], which are the following.

5.1.3.1. Cognitive Evaluation Theory (CET)[52]

This theory was initially introduced to describe the phenomenon where rewards pose a negative effect on intrinsic motivation (Deci, 1971). Although this theory asserts that rewards can decrease the level of intrinsic motivation for an interesting activity or task (while a dull activity or task has no effect), the declination of the intrinsic motivation still depends on the individual perception of the rewards. Specifically, **when the rewards support the perception of individual autonomy and competence, intrinsic motivation is likely to increase** while the intrinsic motivation tend to decrease when the individual perceives the controlling aspect of the rewards.

5.1.3.2. Organismic Integration Theory (OIT)[53]

This theory explains the process of internalization of diverse extrinsic motives, which can be illustrated as a continuum of internalization ranging from external regulation to integrated regulation. As shown in figure 4.4, the continuum of internalization is located at the center of the self-determination continuum (from red to yellow) while the leftmost shade is the state of lacking motivation (amotivation) and the pure intrinsic motivation is on the rightmost.

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[51] Ryan, R. (2009, June). *Self-determination Theory and Wellbeing*. Retrieved May 15, 2011 from http://www.welldev.org.uk/wed-new/network/research-review/Review_1_Ryan.pdf
[52] Retrieved on May 15, 2011 from http://changingminds.org/explanations/theories/cognitive_evaluation.htm
[53] Retrieved on May 15, 2011 from http://changingminds.org/explanations/theories/cognitive_evaluation.htm

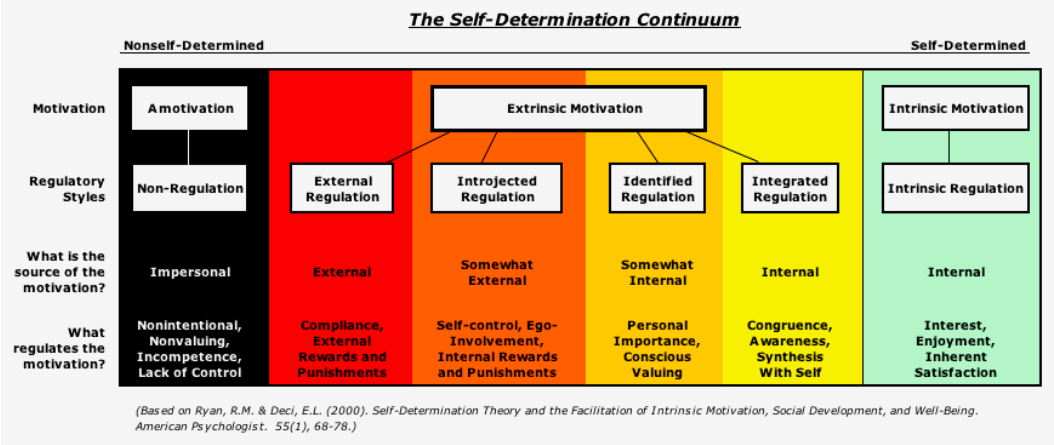


Figure 24: Self-Determination Continuum

On the self-determination continuum, dissimilar shades represent different states of motivation, the description for each of which is summarized in the table below.

Motivation Category	Description
Amotivation	The state of lacking motivation to do things.
External Regulation	An activity is done to purely satisfy some external rewards. For instance, a student who completes surveys for gift cards.
Introjected Regulation	An activity is performed to achieve a reward or avoid a punishment that delights an internal mind such as pride or anxiety. For example, a student who does things to show off their abilities.
Identified Regulation	An activity is completed because a performer considers them personally important. One exemplary scenario is a student who keeps reading books because the content relates to his personal project in the future.

Integrated Regulation	An activity is accomplished because it is congruence with other personal values and needs. For example, a student who always explores a new way to do things because his personal value is creativity.
Intrinsic Motivation	An activity is carried out because it offers great satisfaction to the performer. For instance, a student making a robot or building a LEGO house for his self-satisfaction.

Table 20: Motivation Categories in the Self-Determination Continuum

To effectively engender the internalization, three contextual supports consisting of **autonomy, competence and relatedness** need to be met. In other word, an individual tends to internalize and integrate a practice or value when the individual experiences choices, feel competent to achieve a selected choice and have connection to people who convey the practice or value. Besides, a number of researches around the world show that the greater internalization of cultural practices, the greater wellness and performance the communities are (Ryan & Deci, 2000).

5.1.3.3. Causality Orientations Theory (COT)[54]

This theory describes three types of causality orientations that regulate people's behaviors. Those three types of causality orientations comprise the following:

- **Autonomy-Oriented**: a person acts on what he is interested in
- **Control-Oriented**: a person focuses on the activities offering rewards

[54] Retrieved May 15, 2011 from http://changingminds.org/explanations/theories/cognitive_evaluation.htm

- **Amotivated-Oriented:** a person is internally forced to do things because of anxieties concerning his own competency

5.1.3.4. Basic Psychological Needs Theory (BPNT)

Basic Psychological Needs Theory (BPNT) attempts to address the concept of basic psychological needs by connecting them with wellness. Based on BNPT, each need results in independent effects on wellness. The theory also shows that the satisfaction of aggregate needs indicates individual health and wellness.

5.1.3.5. Goal Contents Theory (GCT)

The theory shows the distinctions between intrinsic and extrinsic goals, leading to the dissimilar impacts on motivation and wellness. Specifically, extrinsic goals such as financial success, appearance, and fame tend not to enhance need satisfaction while intrinsic goals such as community, close relationships, and personal growth are conducive to the need satisfaction. Consequently, the goals toward intrinsic motivation are better contributor to wellness than extrinsic outcomes.

5.1.4. Reinforcement (Reward) Theory

From the perspective of behaviorists, B.F. Skinner has long introduced a theory of motivation stating that the positively reinforced behaviors will be repeated while the negatively reinforced behaviors is less likely to be repeated. Skinner suggested that the positive reinforcement effectively contributes to the behavioral changes and the altered behaviors tend to last longer when comparing to the negative one. However, when a number of studies investigated

this area further, many forms of reinforcements (or rewards) seem to endanger human's behaviors and long-term intrinsic motivation.

5.1.5. The Effect of Reward on Intrinsic Motivation

Although Skinner's theory is reasonable and widely acceptable by most behaviorists, all rewards, in fact, do not affect intrinsic motivation in a uniform way. Many studies also confirm that many forms of reinforcements (or rewards) actually decrease intrinsic motivation. Since dissimilar forms of rewards lead to different intrinsic motivation outcomes, the table below was constructed to summarize all possible reward forms and their effect on intrinsic motivation.

Reward Type	Enhance Intrinsic Motivation?	Rationale	Examination Method & Measurement Value
Positive Feedback (Verbal Rewards)	Depends on the individual perception	Verbal rewards are usually unexpected so the positive feedback tends to enhance intrinsic motivation. Also, if the feedback is regarded as increasing competence, the feedback improve intrinsic motivation	21 studies of free choice intrinsic motivation (composite effect (d) = 0.33); 21 self-reports of interest (composite effect (d) = 0.31)
Tangible Rewards (e.g., materials rewards such as money and prizes;	Mostly **undermines**	Tangible rewards typically promote an external perceived locus of causality for the rewarded behaviors	92 studies of free choice intrinsic motivation (d=-0.36);

tangible rewards such as trophies)		and undermine intrinsic motivation	70 self-reports of interest (d=-0.10)
Unexpected Rewards and Task-Noncontingent Rewards	No effect to intrinsic motivation; Unlikely to undermine	If people are not doing a task to get a reward, they are not likely to experience their task behavior as being controlled by rewards	N/A
Engagement-Contingent Rewards	Significantly **diminished** intrinsic motivation	This type of rewards is prevalent in our daily life. For example, an employee who get exact paid for working on their job but not for their increasing performance	55 behavioral measures (d=-0.40) and 35 self-report interest (d=-0.15)
Completion-Contingent Rewards	**Undermine**	Although completion-contingent rewards provide some affirmation of competence, the overall CET predicts an undermining effect	20 behavioral measures (d=-0.44) and 15 self-report interest (d=-0.17)
Task-Contingent Rewards	Significant **Undermine**	The effect in children is significantly stronger than in college students	74 studies of free choice measure (d=-0.39); 48 studies with a self-reports (d=-0.16)
Performance Contingent Rewards	Depends on individual	The reward can enhance intrinsic motivation if	32 free choice measure (d=-0.28);

	interpretation	receivers interpret the reward as an affirmation of competence. However, it could be interpreted to be a control factor, decreasing sense of autonomy	29 self-reports of interest (no significant)

Table 21: The Effect of Reward on Intrinsic Motivation

Based on the summary above, it is obvious that verbal rewards in general contribute to the increase in intrinsic motivation while other types of rewards have a great tendency to jeopardize intrinsic motivation with the exception of unexpected rewards, task-noncontingent rewards and performance contingent rewards, which significantly depend on the perception and interpretation of each individual. In addition to the table above, the summary of the meta-analytic results of the effects of extrinsic rewards on intrinsic motivation is incorporated into the table below to provide a comparison table of Cohen's composite (d) and effects (k) across reward types.

Reward Type	Sub-Reward Type	d	k
All Rewards		-0.24[a]	(101)
Verbal Rewards		0.33[a]	(21)
	College	0.43[a]	(14)[b]
	Children	0.11	(7)[b]
Tangible		-0.34[a]	(92)
Unexpected		0.01	(9)[b]
Expected		-0.36[a]	(92)
	Task Noncontingent	-0.14	(7)[b]
	Engagement Contingent	-0.40[a]	(55)
	College	-0.21[a]	(12)[b]
	Children	-0.43[a]	(39)[b]
	Completion Contingent	-0.44[a]	(19)[b]
	Performance Contingent	-0.28[a]	(32)
	Maximum Reward	-0.15[a]	(18)[b]
	Not Maximum Reward	-0.88[a]	(6)[b]
	Positive Feedback Control	-0.20[a]	(10)[b]
	Negative Feedback Control	-0.03	(3)[b]

Table 22: Summary of the Meta-Analytic Results of the Effects of Extrinsic Rewards on Free-Choice Intrinsic Motivation, Shown as Cohen's Composite d

Although the verbal rewards help increase intrinsic motivation, it is important to note that three conditions need to be fulfilled to ensure this

expected outcome. First, the individuals must feel autonomous. Second, those individual must not expect any feedback during performing the activity. Third, it must be important for the individual to perform well.

5.1.6. System Design Principle to Promote Human Growth and Development

The ERG theory and the theory of Maslow's Hierarchy of Needs suggest a simple systematic framework that empowers us to anticipate what kinds of behaviors could be expected from an individual at a given state. Since the state of "growth" would promote the human learning and development, a conceptual learning system should create and maintain the learning environment in a way that existence needs and relatedness needs are sufficiently satisfied to allow learners to progress and remain in the final state of growth.

System Design Principle 11: Basic Need Fulfillment
A good learning system must setup and maintain a learning environment in which the learners can sufficiently fulfill their existence needs and relatedness needs.

Table 23: System Design Principle 11

5.2. The language of Intrinsic Motivation

5.2.1. The Language of Goals

The cumbersome development of increasingly complex matrix of diverse reward properties (i.e., expected and unexpected rewards, completion-contingent and performance contingent rewards) led to the development of the

goal language, which offers a much simpler framework to represent a scalable and systematic structure of goals and means. Since the goal language refers to the internal events or mental representations, the goal language can be used over a wide range of influencing variables such as culture, personality and context, allowing psychologists to understand the neutral effects of goals to individual behaviors. Instead of investigating what rewards can do to you, the goal language can illustrate what an individual is willing to do for the rewards.

Figure 25: System of Goals and Means

The structure of this "goals-means" system refers to the relation between the activity and its goal while the substance of the system represents the type of goal that the activity will serve as a mean to attain. For instance, self-determination, competence and mastery as three exemplary goals that can fulfill

individual intrinsic needs (Ryan et al., 1996) while tangible rewards or evaluative pressures are deemed as extrinsic needs.

5.2.2. The Association of Goals to Means

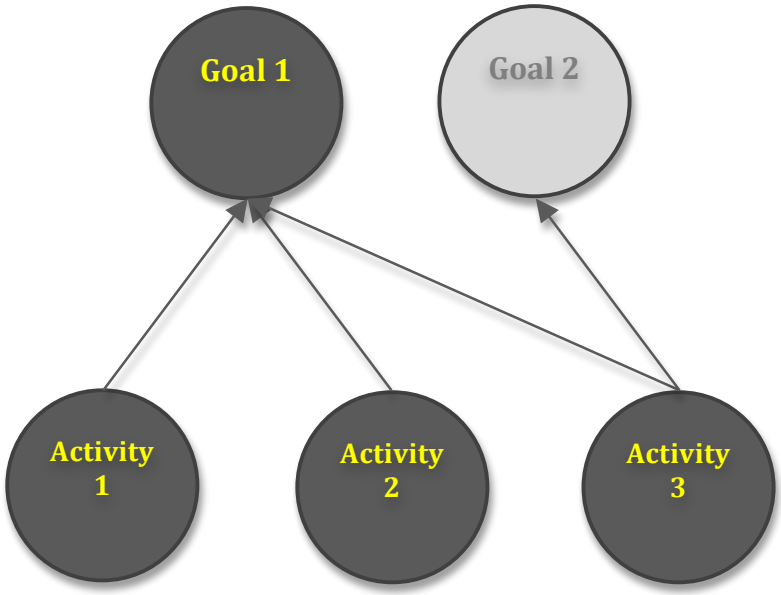


Figure 26: Structural Equifinality

Since there could be numerous means to attain one particular goal, the strength of the association between a goals and a means should decrease when more alternative means are available. For example, there might be many possible ways for one to choose to get in shape. While some might consider only a single means (i.e., running), others could weigh many different activity options (i.e., running, lifting weights and playing basketball). This phenomenon where the association between a goal and a single means is weakened by the presence of other available means is referred as “mean disassociation”.

5.2.3. The Association of Means to Goals

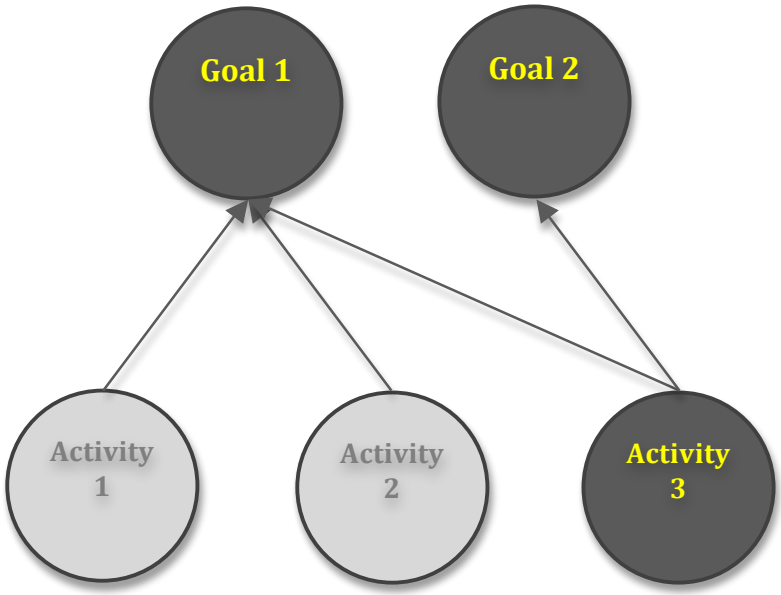


Figure 27: Structural Multifinality

On the contrary with equifinality, multifinality is referred to the phenomenon where one single means can serve more than one goal. For instance, the simple act of walking can be viewed as a means of transportation in one context and a means of exercising in another context. Also, if one strongly associates the act of jogging with the goal of getting in shape, one may be less likely to consider jogging as a means for getting to school. The weakening of association between an activity and a given goal because of increasing associations with other goals is referred as "goal disassociation".

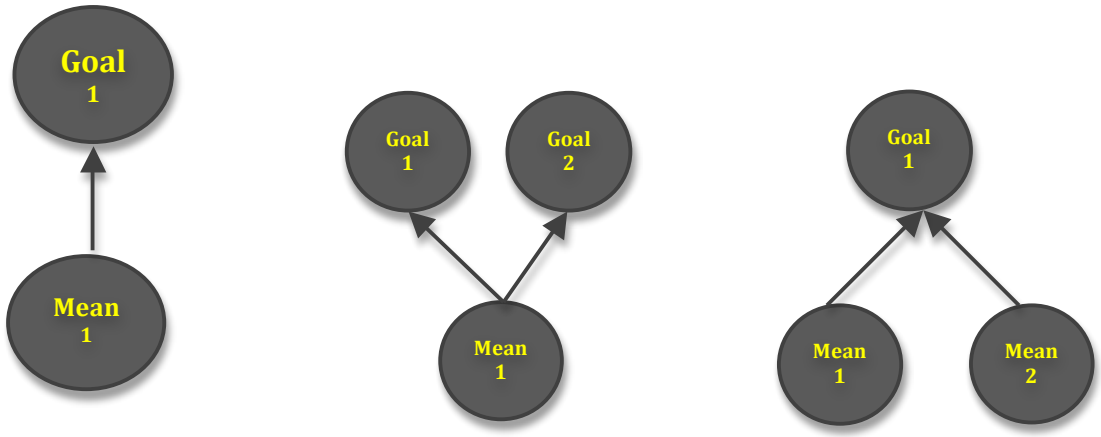
5.2.4. Intrinsic and Extrinsic Associations

Based on the goal structure outlined above, the intrinsic motivation of an activity to a goal is optimized when

- The activity is always engaged in the pursuit of the goal
- The activity is not associated with the attainment of any other goals

- No other activities associate with the attainment of the goal

The goal structure of intrinsic is illustrated in the figure A below.



(A) Intrinsic (B) Extrinsic Goal Disassociated (C) Extrinsic Means Disassociated

The structural perspective suggests that intrinsic motivation can decrease when there is extrinsic motivation, leading to either "goal disassociation (B)" or "mean disassociation (C)".

5.2.5. Implications of Goal, Activities and their Associations

Committing to one particular goal can be viewed as one aspect of intrinsic motivation. While goal commitment and enjoyment may depend on the substantive quality of the goal, the stronger goals-means association contributes to stronger commitment and greater enjoyment in the pursuit of the goal. In the same vein, the greater association between an activity and a goal results in a greater tendency for the activity to be perceived as the most dominant means to fulfill the goal.

According to the model of goals and means, the qualities of one's specific goal could transfer to the activities in the pursuit of that particular goal. One transferable quality is goal commitment. The stronger the relation between goal and means, the more likely it was that a commitment to the goal transfers to a commitment to the associated activity. For example, an individual who commits to becoming educated, it is likely that the individual will commit to studying when studying activity is strongly tied to the educational goal.

5.2.6. System Design Principle to Promote Intrinsic Motivation

The system of goals and means constructed by the goal language shed the light on how an individual's intrinsic motivation can be enhanced and optimized. A good learning system should help learners identify their intrinsic needs before introducing learning activities that strongly tied to the learning goals fulfilling their intrinsic needs. As a concrete example, we can strengthen the association between the act of running and the goal of getting in shape by reframing the notion that running is one of the best way for one to get in shape when comparing to other means. This may enhance both activity commitment and enjoyment because the qualities are transfer from the goal. From this rationale, we can form a new system design principle into the proposed list of system design principle.

System Design Principle 12: Highlighting Association Between Learning Goals and Learning Intrinsic Needs
A good learning system should enhance learner's intrinsic motivation in learning activities by introducing and highlighting the learning activities that have strong association to the specific learning goals thought to fulfill the learner's intrinsic needs while lessening the associations of the learning activities toward other "extrinsic" goals.

Table 24: System Design Principle 12

5.3. Process Model of Intrinsic Motivation

In 1991, Harackiewicz and Sansone formalized a process model of intrinsic motivation illustrating how the individual goals affect the level of individual intrinsic motivation. Individuals tend to have "perceived goals" – some ideas on what to accomplish before beginning to perform activities – which are influenced by multiple determinants. One class of the determinants involves contextual factors such as the offer of performance-contingent reward while another class of the determinants relate to personality factors such as individual differences in achievement orientation. These effects represent as A paths in figure 28.

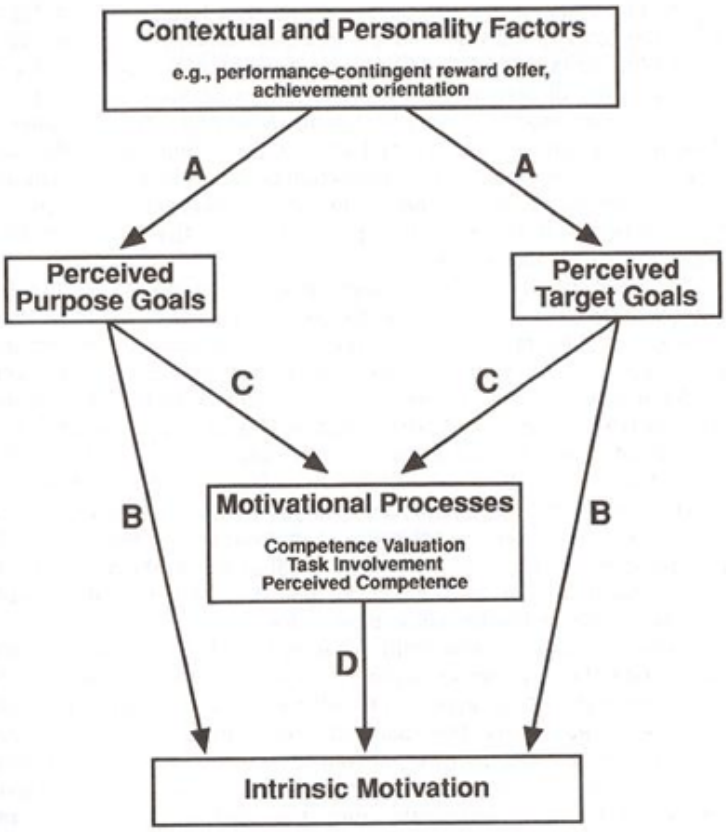


Figure 28: Process Model of Motivation

Since perceived goals can range from low-order goals that are concrete and situationally specific (i.e., "I want to read a chapter of my psychology text tonight") to high-order goals that are broad, cross-situational and consistent over time (i.e., personal strivings), Harackiewicz and Sansone believe that intrinsic motivation is best interpreted as specific to a particular activity at a particular time. Thus, they focus on the two levels of goals at the lower end of the goal continuum: perceived purpose goal and perceived target goal.

The perceived purpose goals reflect reasons **why** an individual desires to engage in a task (i.e., to develop or demonstrate one's competency, to have fun, to socialize) while the perceived target goals reflect **what** specific actions needed to accomplish overarching perceived purpose goals. For instance, when an

individual is offered a performance-contingent reward, he is likely to hold target goals that reflect the specific performance standard meeting the performance contingency (i.e., scoring more than 20,000 points). Both perceived purpose goals and target goals create the motivational context that influences how an individual approaches and experiences an activity (represented as C paths in figure 4.8).

The motivational context is the result of internal motivational processes where three distinct properties of performance-contingent rewards are identified: evaluative threat, competence feedback and symbolic cue value[55].

- **Evaluative threat** affects the motivational processes when an individual realized that a reward depends on his or her performance evaluation, leading to the feeling of pressured or being controlled. As a consequence, the individual is likely to enjoy the activity less, resulting in the decrease of the intrinsic motivation if there is nothing to counter this effect.
- **Competence Feedback** can repair some damage caused by evaluative threat because a number of studies have documented that positive competence feedback for skill-based activities contributes to the increase on intrinsic motivation. Not only is perceived competence an important determinant of subsequent interest but also some studies have shown that the receipt of performance-contingent rewards can

[55] Sansone, C. & Harackiewicz, J. (2000). Intrinsic and Extrinsic Motivation: The Search for Optimal Motivation and Performance (P.82-90). Orlando, FL: Academic Press.

enhance perceived competence relative to no-reward and no-feedback control.

- **Symbolic Cue Value** can positively influence intrinsic motivation if an individual regards the symbolic cue value as a reward for the next level of his or her competence. For the reason, the perception to the performance-contingent rewards is the key to determine if the rewards will yield to the positive effect or null effect. Cue value could be greater if the rewards symbolize higher levels of achievement (i.e., a reward in a state tournament has a great value than in a class).

5.3.1. System Design Principle to Promote Positive Net Effect on Intrinsic Motivation

To eradicate the possible negative effect caused by the evaluative threat, a good conceptual learning system should let the learners define their own self-assessment method. Since the self-assessment approach seems difficult to implement in reality in the current era, the self-assessment approach is the ideal way to maintain individual intrinsic motivation. For this reason, the good conceptual learning system must find a right balance between wide-accepted standard assessment and individual self-assessment.

System Design Principle 13: Self-Assessment on Learning Progress
A good learning system should offer a self-assessment mechanism for learners to realize their learning progress.

Table 25: System Design Principle 13

Moreover, to increase the impact of both competence feedback and cue value, performance-contingent rewards given within the designed conceptual learning system should instill feelings of competence, accomplishment and pride in learners. By consistently providing a mix of verbal rewards and positive symbolic cue value (stars, red bows) to praise about learners' efforts to learn, the intrinsic motivation of the learners will increase over time. As a result of this analysis, we conceive another new system design principle that should be put into the proposed list of system design principle as follow.

System Design Principle 14: Positive Feedback and Symbolic Cue Value
A good learning system should consistently provide positive verbal feedback and positive symbolic cue value for their learning efforts.

Table 26: System Design Principle 14

6. System Architecture of Intrinsically Motivated Learning Systems

A learning system can be conceived as a dynamic shared space[56] between a learner entity and a mentor entity where collective knowledge and values are constantly exchanged in between, resulting in the knowledge construction and value absorption in both parties. A learning system could appear in a form of a traditional learning system (i.e., a traditional classroom, a colloquium, a professional training program or even a business meeting) or a technology-driven learning system (i.e., an e-learning system, a flight simulator, a company information system, a professional training system).

Similarly, an intrinsically motivated learning system shares the same concept of a learning system. However, an intrinsically motivated learning system is more specialized and specifically designed to enhance learner's intrinsic motivation in learning. Two minimum desired outcomes of an intrinsically motivated learning system are:

- A transformation of a learner's mindset from being a passive learner to becoming an active and self-directed learner, and
- An enhancement of learner's intrinsic motivation toward learning

The focus for this chapter is to propose a high-level system architecture for intrinsically motivated learning systems that can promote high school students' intrinsic motivation in learning. The proposed system architecture was

[56] A Youtube video that effectively communicates the idea of shared space – Retrieved May 15, 2011 from http://www.youtube.com/watch?v=bsHmrvmeuWs

developed as a blueprint not only for designing new intrinsically motivated learning systems from scratch but also for configuring existing learning systems in such a way that the modified learning systems can enhance students' intrinsic motivation in learning. In other words, the proposed system architecture is not a framework for just one particular intrinsically motivated learning system but a wide range of implementable learning systems where the mutual objective is to boost students' intrinsic motivation in learning.

6.1. System Architecture of Learning Technology Systems

To compatibly interoperate with other related systems (i.e., learning management systems, content management systems and such), the proposed system architecture of self-motivated learning systems are designed upon IEEE standard for learning technology (as known as Learning Technology Standard Architecture or LTSA)[57]. The LTSA standard offers universal system architecture for various learning technologies such as an e-learning system, a flight simulator or even an expert system. According to the LTSA, the system architecture of learning systems can be stratified into five layers, presented below from the highest layer (layer 1) to the lowest layer (layer 5):

- Layer 1 – Learner and environment interactions – focuses the interactions between learners and learning environments. The interactions could be a form of learner's knowledge acquisition, knowledge transfer, discovery of knowledge through interaction, for example. Detailed information can be looked up at the Annex C.2 inside the IEEE standard documentation

[57] IEEE Computer Society sponsored by Learning Technology Standards Committee. (2003). *IEEE Standard for Learning Technology-Learning Technology Systems Architecture (LTSA).* Retrieved May 15, 2011 from http://ieeexplore.ieee.org/xpls/abs_all.jsp?isnumber=28129&arnumber=1257919&tag=1

(LTSA).

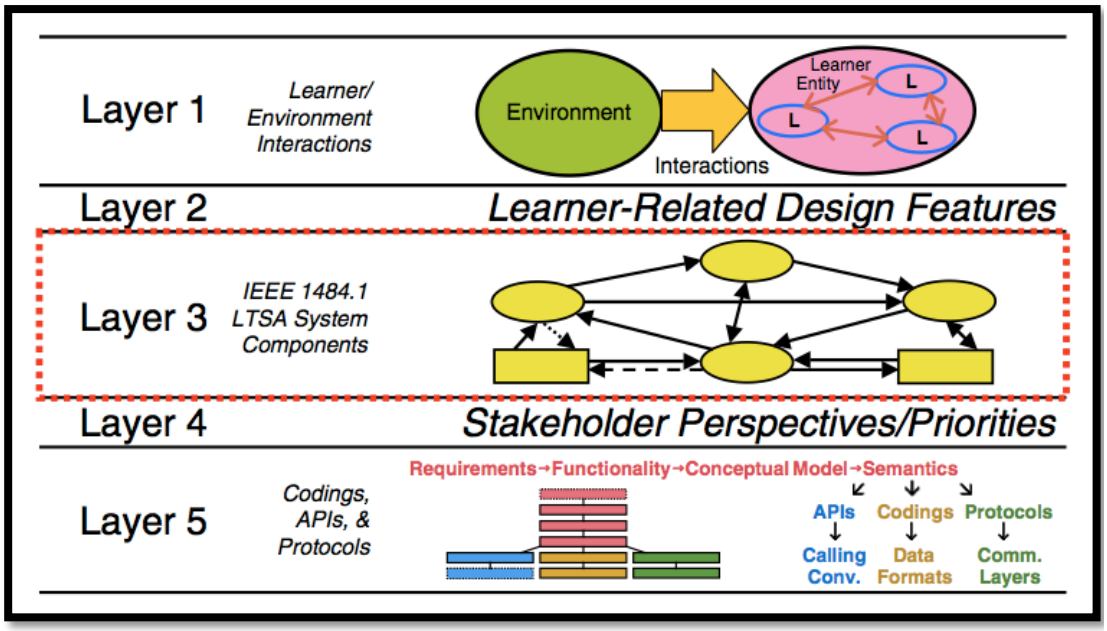


Figure 29: LTSA Abstraction-Implementation Layers

- Layer 2 – Learner-related design features – concentrates on the needs of the learners, which seem to vary based on a group of learners (i.e., a group of high school students might be more interested in SAT than a student group in a primary school).
- Layer 3 – System components – provides the component-based architecture identified in human-centered and pervasive features. This is the only normative layer in this standard while other layers are informational. This layer will be elaborated more in detail in the next section.
- Layer 4 – Implementation perspectives and priorities – describes learning technology systems from a variety of stakeholder perspectives by referencing possible subsets derived from the layer 3 – system components layer. Within the LTSA standard documentation, a non-exhaustive list of over 120 stakeholder perspectives was congregated in

the Annex A. According to the standard, LTSA components are verified and validated in significant systems, stakeholders and industries, demonstrating the universal applicability of the LTSA.

- Layer 5 – Operational components and interoperability – care of the aspect of operability and interoperability among learning systems. Specific coding, APIs, protocols and system interfaces are considered to be within this layer.

From the perspective of system designers of learning technologies, the human aspect of learning system (layer 2) appears more important than a particular media format (layer 5). The five layers introduce "a big picture" rather than the "details", which help a system architect design a large-scale learning technology in a more systematic way.

6.1.1. System Components of Learning Technology System Architecture

Since Layer 3 provides a framework for analyzing interoperability requirements among major systems in learning industries, the details of system components of learning technologies (layer 3) is excerpted in this section. As shown in the figure 31, ovals represent processes that are "alive" and able to transform its inputs into outputs. For example, a data transformation process transforms data inputs into data outputs. Solid arrows represent data flows while dashed arrows represent control flows. Lastly, rectangles represent stores holding information.

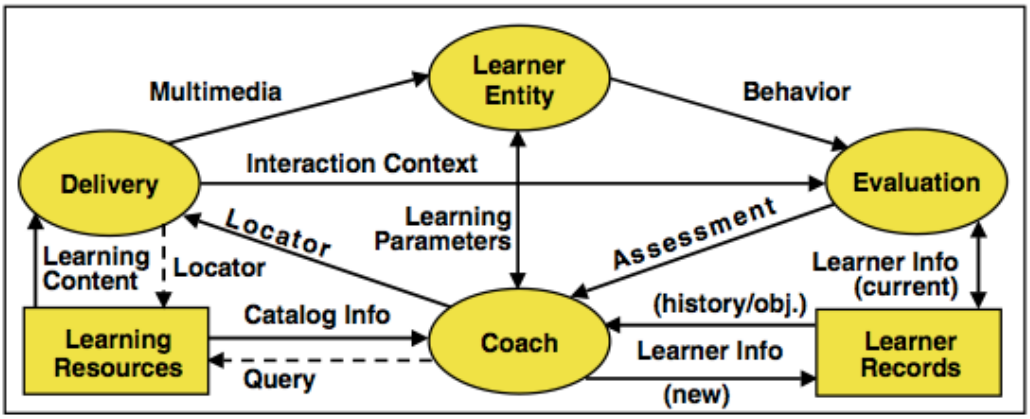


Figure 30: LTSA System Components

The learning technology system architecture (LTSA) consists of the following system components (as literally defined in the standard documentation):

- Four processes: learner entity, evaluation, coach and delivery.
- Two stores: learner records and learning resources.
- Thirteen data flows: learning parameters, behavior, assessment information, learner information (three times), query, catalog info, locator (two times), learning content, multimedia and interaction context.

Each process and its related components in the system components can be briefly described below:

1. **Learner Entity**

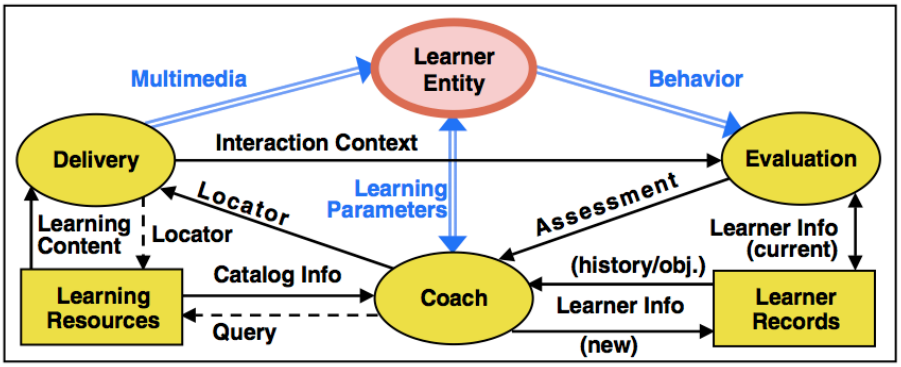


Figure 31: LTSA System Component - Learner Entity

Learner Entity (emphasized in red oval) is an abstracted process representing a human leaner, a group of individual learners, a group of collaborative learners and so on. A possible input can be a multimedia presentation via the **multimedia** (highlighted in blue) dataflow whereas an output could be the behaviors of learners. There is also a two-way data flow between the learner entity and coach, labeling as **learning parameters**, which represent information exchange. The information exchange can be preferred learning styles and strategies, which may be chosen by either the learner entity (one-way negotiation such as assertion and inquiry), the coach (one-way negotiation such as an assertion or inquiry), both the learner entity and the coach (two-way negotiation), or an external authority (e.g., parents, teachers, institutions, or content developers). The information exchange covers cognitive limitations, physical limitations and/or cultural adaptation parameters, which define an appropriate form of the learning process.

2. **Evaluation**

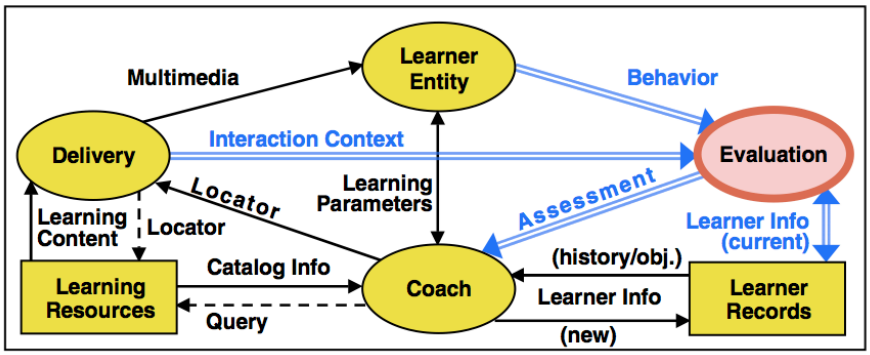


Figure 32: LTSA System Component - Evaluation

Evaluation is an abstracted process that may produce measurement of the learner entity. The main input of the evaluation process is the observable behaviors via the **behavior** data flow while the **interaction context** data flow could provide additional information for the evaluation process to offer an appropriate evaluation (i.e., real-time spell-checking applications can help teachers evaluate the learners' essay), resulting in the assessment information to the coach via the **assessment** data flow. The two-way data flow "**learner information**" represents the possibility of storing and retrieving learner records (i.e., grades, learning preference) if any.

3. **Deliver**

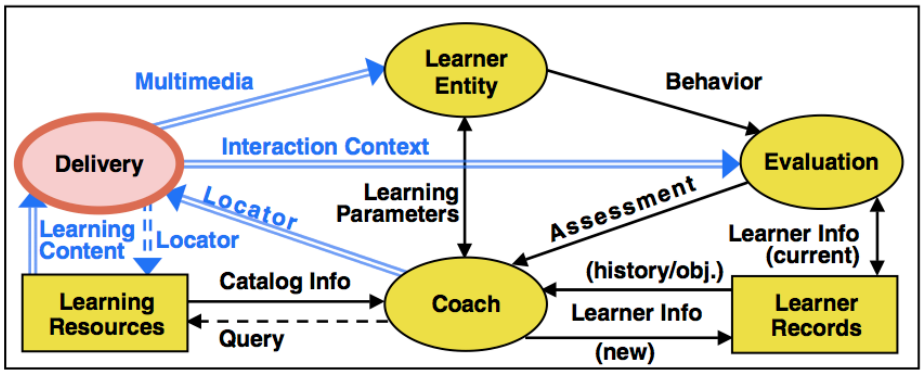


Figure 33: LTSA System Component - Delivery

Deliver is an abstracted process that may transform information via a **learning content** data flow from a **store of learning resources** into a presentation (i.e., static, interactive, collaboration, involve experiments and discovery) and may then be transferred to the learner entity via a **multimedia** data flow. Because the LTSA focuses on computer-based learning technologies, the **locator sent by coach** (i.e., a web URL) to the delivery process is the one-way data flow to point out relevant learning contents while the **locator sent by delivery** to the learning store is a control flow that identifies (i.e., a web URL) for specific learning resources.

4. **Coach**

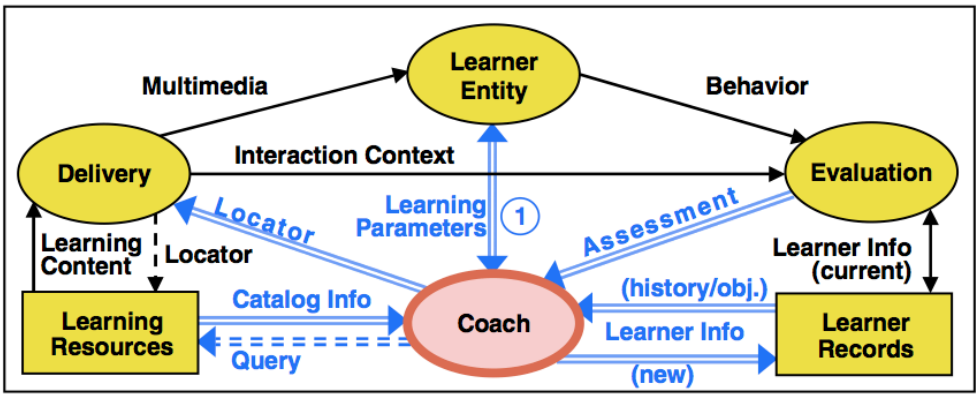


Figure 34: LTSA System Component - Coach

Coach is an abstracted process exchanging information with the learner entity. The coach process may also receive learner's information (i.e., current state) from the evaluation process via the **assessment** link and from the **learner records** data store to determine the optimal learning experience. The coach can also update learner information back on the learner records data store. Furthermore, the **query** data link may be sent from the coach process to search for appropriate learning resources, which will subsequently return catalog

information via the **catalog information** data link. The coach may then pass the selected locators from then catalog information to the delivery process for further presentation to learner entity.

6.2. System Architecture of Intrinsically Motivated Learning Systems

The proposed system architecture of intrinsically motivated learning systems is not only designed upon the IEEE standard but also based on the system architecting process taught in ESD.34 System Architecture class at MIT. As indicated in the LTSA standard level 4, the needs analysis of stakeholders contributes to a successful system architecture. For that reason, the needs of both primary system beneficiaries and relevant stakeholders of typical learning systems must be first identified in the process of system architecting before the needs of system stakeholders are prioritized by their benefits. Then, those needs are interpreted as system goals, which are subsequently sorted by their delivered values to all system stakeholders. It is importantly note that chapter 8 shows a set of questionnaire results to ensure validity of the system architecture and to check whether the essential needs of primary system beneficiaries are met or not. The system architecting process is illustrated in the figure below.

Figure 35: System Architecting Process - Needs to Goal Approach Framework

6.2.1. Stakeholder Analysis

6.2.1.1. Primary System Beneficiaries and Needs

Learner Entity: Obviously, the primary beneficiary of learning systems is a learner entity. Since the focal point of the thesis is high school students, the needs of a typical high school student are used as independent variables for the design of the proposed system. Based on the 2009 High School Survey of Student Engagement (HSSSE), a primary reason why a typical high school student goes to study at school is to get a high school degree because the degree will allow them to advance their study. While 73% of survey respondents indicated, "I want to get a degree and go to college" as a particular need for going to school, "I want to get good jobs" came second in the list (67% of the respondents). The survey classified three main purposes for which students attend school as follow:

- **Academic purpose:** get a high school degree and pursue future schooling and/or work
- **Social purpose:** meet peers and friends
- **Family purpose:** students feel an obligation to family to pursue schooling

Unfortunately, less than half of the students express that they want to go to school because they want to acquire new knowledge (41% of respondents), to enjoy the learning experience (36%) and to have interactions with teachers (23%). This survey result revealed that a large number of students lacked intrinsic motivation in learning. They didn't consider the learning enjoyment and obtaining knowledge as their important needs (highlighted in red in figure 36). Instead, they would rather put more value on tangible extrinsic motivation such

as a high-test score and a good grade. This finding confirms the need for self-motivated learning systems.

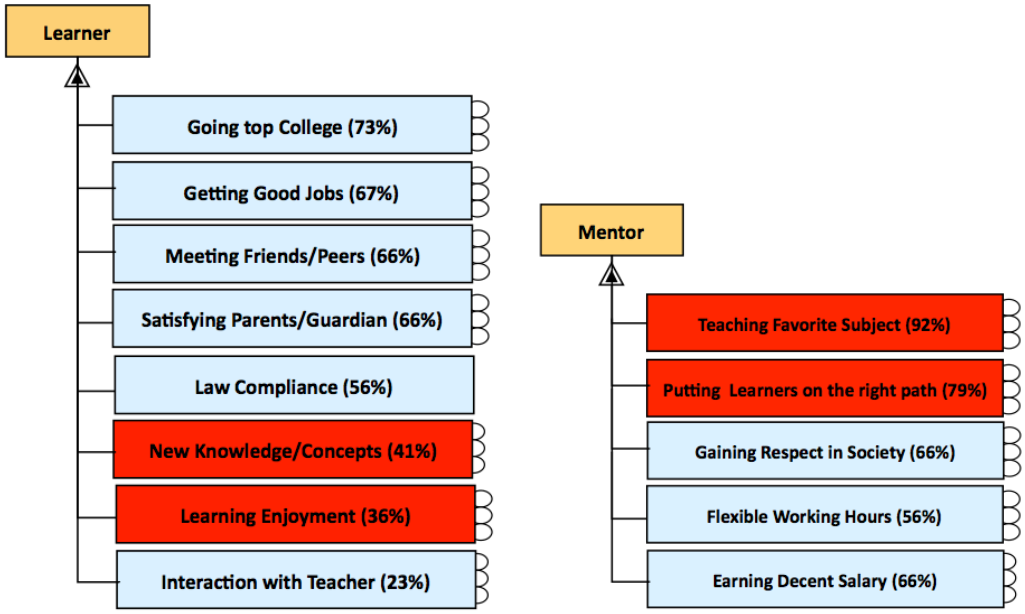


Figure 36: Learner and Mentor as System Beneficiary

Mentor Entity: Another primary learning system beneficiary is a mentor entity, which is a high school teacher in this context. The needs of teachers can be considered as selfless needs since many teachers emphasized a love for children and a desire to do something meaningful as motivational factors for pursuing this profession[58]. Based on the 2008 MetLife Survey of the American Teacher – Past, Present and Future, 98% of teachers responding the survey agreed that they love to teach. 66% of teachers agreed that they feel respected in today's society and earn a decent salary rate.

[58] Metlife. (2006). *2006 MetLife Survey of the American Teacher: Expectations and Experiences*. Retrieve May 15, 2011 from http://www.eric.ed.gov/PDFS/ED496558.pdf

In addition, the Spring 2007 report from the National Comprehensive Center for Teacher Quality and Public Agenda[59] unveiled that most secondary school teachers chose to teach because they want to teach a subject they love and get students excited about it and to help shape student lives to success (79% of respondents). 56% of the respondents also viewed the flexible working hours (such as summer time off) as another decision factor. From this information, the beneficiary can be illustrated in figure 36. Interestingly, the survey results imply that teachers had higher intrinsic motivation for teaching than students had for learning. This discrepancy demands better value-exchange alignment between these two primary system beneficiaries.

6.2.1.2. System Stakeholders and Needs

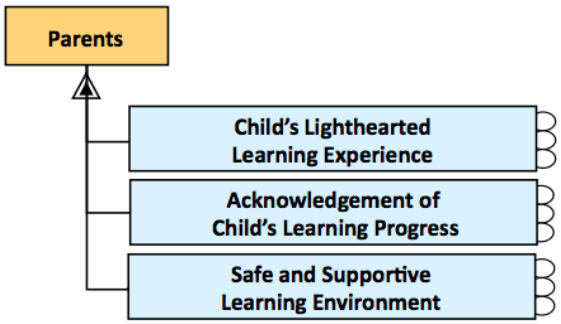


Figure 37: Parents as System Stakeholder

Parents: For an adult learner, parents might not be considered as a vital stakeholder of learning systems. However, if a learner is a high school student, parents is a very critical stakeholder as parents not only contribute to student's behaviors and attitudes toward learning but also significantly affect the learner's choices of future professions, especially in Asian countries. Based on the Internet

[59] National Comprehensive Center for Teacher Quality and Public Agenda. (2007). *Lessons Learned: New Teachers Talk About Their Jobs, Challenges and Long-Range Plans*. Retrieved May 15, 2011 from http://www.tqsource.org/publications/LessonsLearned1.pdf

research regarding parent's needs, child's happiness[60] appears to be the first priority for all typical parents. The parents also expressed the need for safety, discipline and a caring learning environment[61], which comes before the need for their child's learning progress[62].

Education institutions: Education institutions are an indispensable learning system stakeholder that traditionally helps centralize a wide-range of educational resources including, but not limited to teachers, friends, materials and tools. Without education institutions, it would be very expensive for a learner to obtain an education due to a problem of the economies of scale. For that reason, the education institutions empower students to enjoy rich learning environments and a variety of learning choices at a more affordable cost. Based on the High School Survey of Student Engagement (HSSSE) in 2009, a safe and supportive learning environment appears as an important factor for student's school attendance, which indicates that one important need of education institutions is to maintain such a learning environment. Professional teachers, responsible students and public recognition are also identified as the mutual needs of conventional education institutions.

[60] University of Michigan (2007, December). Parents Want Teachers Who Make Children Happy. *ScienceDaily*. Retrieved May 16, 2011, from http://www.sciencedaily.com/releases/2007/12/071206163305.
[61] Philly.com. (2010, July). *What do parents want from school?* Retrieved May 15, 2011 from http://articles.philly.com/2010-07-15/news/24968079_1_charter-schools-parental-choice-school-parents
[62] Ad Hoc Parent Engagement Policy Development Committee of the Parent Collaborative. (2006, December). Los Angeles Unified School District Parent Needs Assessment Survey Results. Retrieved May 15, 2011 from http://latimesblogs.latimes.com/parent_needs_assessment_report-FINAL.pdf

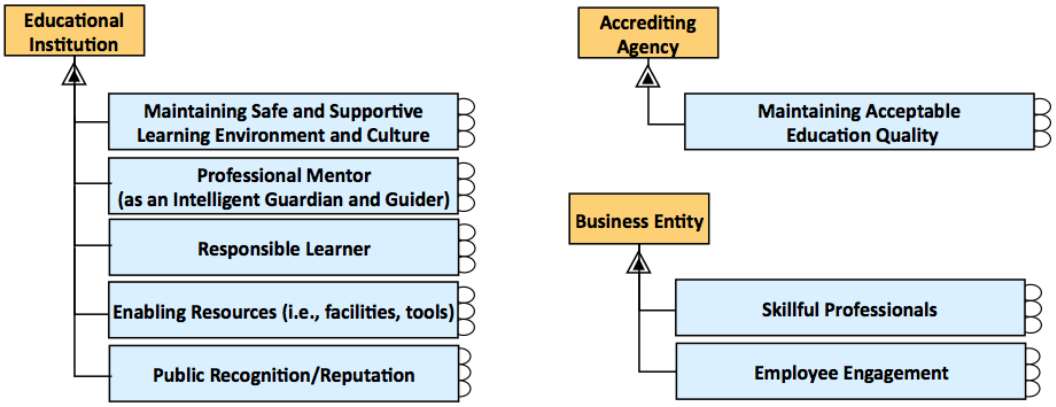


Figure 38: Educational Institution, Accrediting Agency and Employer as Relevant System Stakeholder

Accrediting agencies: Accrediting agencies are a relevant learning system stakeholder whose critical need is to ensure that education provided by institutions meets acceptable levels of quality. The accrediting agencies are responsible for developing evaluation criteria and conduct peer evaluations to assess whether or not accredited institutions periodically meet those criteria.

Business Entity: Although the salient primary need of most business entities is the increase in shareholder value and the likes, the needs for qualified human resources are emphasized in this context because learning systems for high school students are the current focus. As a consequence, the needs of employers for skillful professionals and employee engagement appear critical to the success of all business entities.

6.2.2. Stakeholder Needs Characterization and Prioritization

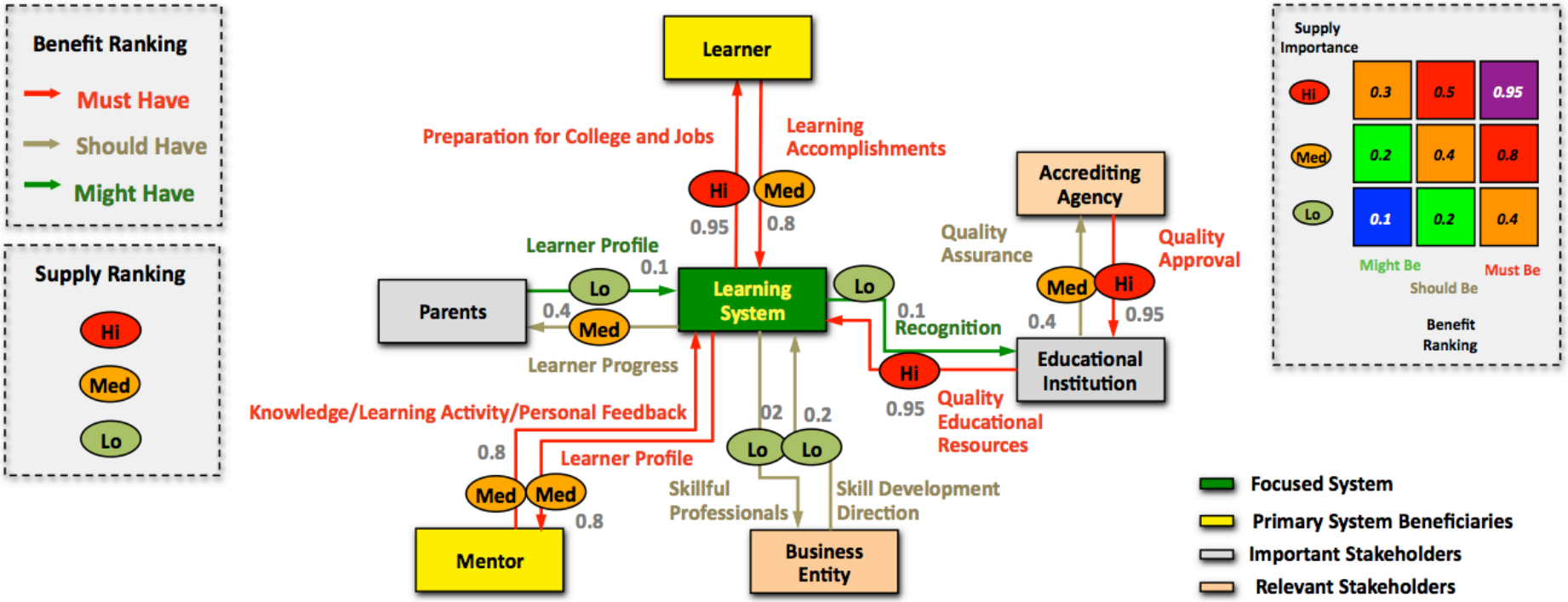


Figure 39: Stakeholder Network of a Learning System

Once the needs of stakeholders are identified, the simplified stakeholder network is illustrated in the figure 39 accordingly. The needs of a learner entity and a mentor entity appear more important than other system stakeholders, which corresponds to the paper on E-learning stakeholder analysis[63] in which the research team concluded that students and mentors must provide feedback to

[63] Wagner, N., Hassanein, K., & Head, M. (2008). Who is responsible for E-Learning Success in Higher Education? A Stakeholders' Analysis. *Educational Technology & Society 11* (3), 26-36. Retrieved May 15, 2011 from http://www.ifets.info/journals/11_3/3.pdf

improve the mutual learning experience. The team also developed the E-learning stakeholders' responsibility matrix as a starting point for new e-learning initiatives. The summary matrix of the E-learning stakeholders' responsibility is excerpted below.

	Student	Instructor	Institution	Content Provider	Technology Provider	Accreditation Body	Employer
Student	• participate in collaborative exercises to enhance learning • share experiences and encourage use	• participate proactively in exercises • provide feedback regarding overall effectiveness	• use e-learning technologies according to institutional policies	• provide feedback regarding the appropriateness of content for e-learning	• provide feedback regarding the effectiveness of technologies	• Demand accreditation for e-learning programs • Provide feedback	• promote the validity of e-learning during interviews
Instructor	• provide effectively designed courses incorporating e-learning content • provide technical and motivational support to encourage use	• share experiences and encourage use • promote standardization	• use e-learning technologies according to institutional policies and standards	• ensure protection of copyrights • provide feedback regarding the level of effectiveness experienced by students collectively	• provide feedback regarding the effectiveness of technologies	• adhere to accreditation standards	• educate on the validity of e-learning
Institution	• standardize the e-learning experience across courses • provide technical support • protect sensitive student information	• provide training in instructional design and technology • provide technical support • provide incentives • enforce standardization	• recognize e-learning credits • share e-learning experiences and courses • encourage standardization	• ensure protection of copyrights • provide funding for content development	• provide feedback to improve future versions • supply appropriate infrastructure to support technology	• adhere to accreditation standards • provide evidence for quality assurance	• seek course accreditation to provide evidence for quality assurance • educate on the validity of e-learning
Content Provider	• select appropriate content and media for e-learning • comply with usability standards	• provide content that meets course & program needs • comply with learning & usability standards	• provide content that meets institutional needs • Comply with learning standards	• comply with standards for interoperability	• comply with standards for interoperability	• adhere to accreditation standards	• provide content relevant to work environment
Technology Provider	• consider learning principles when designing • allow adjustments for individual learning styles • comply with usability standards	• consider usability and teaching principles when designing • comply with learning & usability standards	• comply with standards for interoperability • provide technical support and training	• comply with standards for interoperability • Provide technical support	• comply with existing standards, and collaborate to develop new standards when necessary	• adhere to accreditation standards	• provide an effective learning environment to maximize learning of potential employees
Accreditation Body	• enforce standards to ensure quality of accredited courses	• provide clear guidelines for requirements	• provide clear guidelines and timely services	• provide clear guidelines for requirements	• provide clear guidelines for requirements	• collaborate to ensure consistency	• enforce effective standards to ensure quality of graduates
Employer	• recognize the validity of e-learning	• provide feedback regarding success of graduates	• provide feedback regarding success of graduates	• provide feedback regarding relevance in workplace	• provide feedback regarding success of graduates	• ensure that standards provide appropriate measures	• share experiences and encourage acceptance of e-learning

Table 27: E-Learning Stakeholders' Responsibility Matrix

The needs of beneficiaries and stakeholders expected from a learning system are subsequently sorted by their priorities in the diagram below. Note that only needs inflows from immediate stakeholders and needs outflows to immediate stakeholders are considered in this case for simplicity.

Figure 40: Stakeholder Needs Priority[64]

After prioritizing the needs, we can perceive that a learning system must sufficiently prepare learners for college and getting jobs (with importance level at 0.95[65]), acquire quality educational resources from accredited education institutions (0.95) and provide a mentor learner profile (i.e., learning style, historical academic records, competency, background, working experiences)(0.8).

[64] Red color indicates critical needs, yellow color indicates moderate needs and green color indicates desired needs

[65] The importance level is calculated based on the matrix between benefit ranking and supply importance shown at the top right in Figure 6.6

Furthermore, the learning system should be able to track learning progress and accomplishments (0.6[66]) and construct learner profile (0.45[67]) while the learning system might take skill development direction from business entities into consideration (0.2) and train skills needed for professionals (0.2).

6.2.3. Interpreting Needs As Goals

To reduce ambiguity and increase clarity of the designed system architecture for intrinsically motivated learning systems, a representative system goal (known as system problem statement in business contexts) is synthesized based on the integrated interpretation of the top-priority needs of system beneficiaries and stakeholders. Because the system architecture is specifically designed for learning systems where the objective is to enhance students' intrinsic motivation in learning without extrinsic human interventions, the needs for the social aspect of a learner entity (i.e., meeting peers, satisfying parents, law compliance and interacting with teachers) are not advocated in the current design of system architecture. As a result, the proposed system architecture will only accommodate the learner's needs for going to college, getting good jobs, acquiring new knowledge and enjoying learning experience while including other three most critical needs from stakeholders analysis (shown in red circle in figure 40), which comprise the system capabilities of preparing learners to be successful professionals, the ability to track learning progress and a feature of facilitating communications between mentors and learners, into a list of important system features.

[66] The importance value of this need (0.6) is normalized and shared between the importance level of the same need for parents (0.4) and learner (0.8)
[67] The importance value of this need (0.45) is normalized and shared between the importance level of the same need for parents (0.1) and mentor (0.8)

6.2.4. System Problem Statement

To develop a primary system problem statement for intrinsically motivated learning systems, several findings in the High School Survey of Student Engagement (HSSSE) in 2009 are listed to support the assertion that making meaningful associations between selected professional goals and high school learning activities within a student's zone of proximal development (ZPD) could not only satisfy the needs of high school's students but also help increase student's interest in learning activities and student's intrinsic motivation in learning. Those supportive findings are:

1. 42% of respondent considered "Material was not relevant to me" as a reason for their boredom.
2. 42% of the students who considered dropping out did so because they did not see the **value** in the homework they were being asked to do.
3. 33% of respondents said that "homework was not challenging enough" creating their boredom whereas 26% of respondents said that "homework was too difficult", resulting in their loss of motivation in learning.

The first and second findings emphasized the need for making the meaningful associations between learning activities and professional goals while the third fact called for learning activities within the zone of proximal development (ZPD) for each individual student due to their differences in competence. Moreover, interest in an activity comes from two appraisals (Silvia, 2005b; Silvia 2006): Novelty-complexity of an event – the evaluation of an event as new, unexpected, complex, hard to process, mysterious or obscure and Comprehensibility (or coping-potential) of an event – the evaluation of personal

skills, knowledge and resources to deal with an event. This research result implies that if the learning activities are new, complex or mysterious but comprehensible and within the student's ability to cope, the learning activities will become more interesting. This implication confirms that the need for each individual student to receive a set of personalized learning activities within their individual zone of proximal development (ZPD) to make the learning experience more interesting, which then increases student's intrinsic motivation as a result.

Along with the revised student's needs and selected stakeholders' needs, the system architecture is also designed to cope with the educational challenges in developing countries such as limited access to high quality teachers. For this reason, the system architecture must be used as a blueprint for affordable intrinsically motivating learning systems, resulting in a system problem statement to clarify the primary goal of the designed system architecture.

> ***"To** enhance high school student's intrinsic motivation in learning; **By** making meaningful associations between selected professional goals and high school learning activities within student's zone of proximal development (ZPD); **Using** a self-directed tool"*

The notion of a self-directed tool is to promote freedom to choose their own learning materials and professional goals of their interest, as freedom (also known as autonomy) is one contributing factors for intrinsic motivation[68].

[68] White and deCharms proposed that the need for competence and autonomy is the basis of intrinsic motivation and behaviour – Retrieved May 15, 2011 from http://en.wikipedia.org/wiki/Self-determination_theory

The system problem statement can be mapped to the object process diagram shown in figure below.

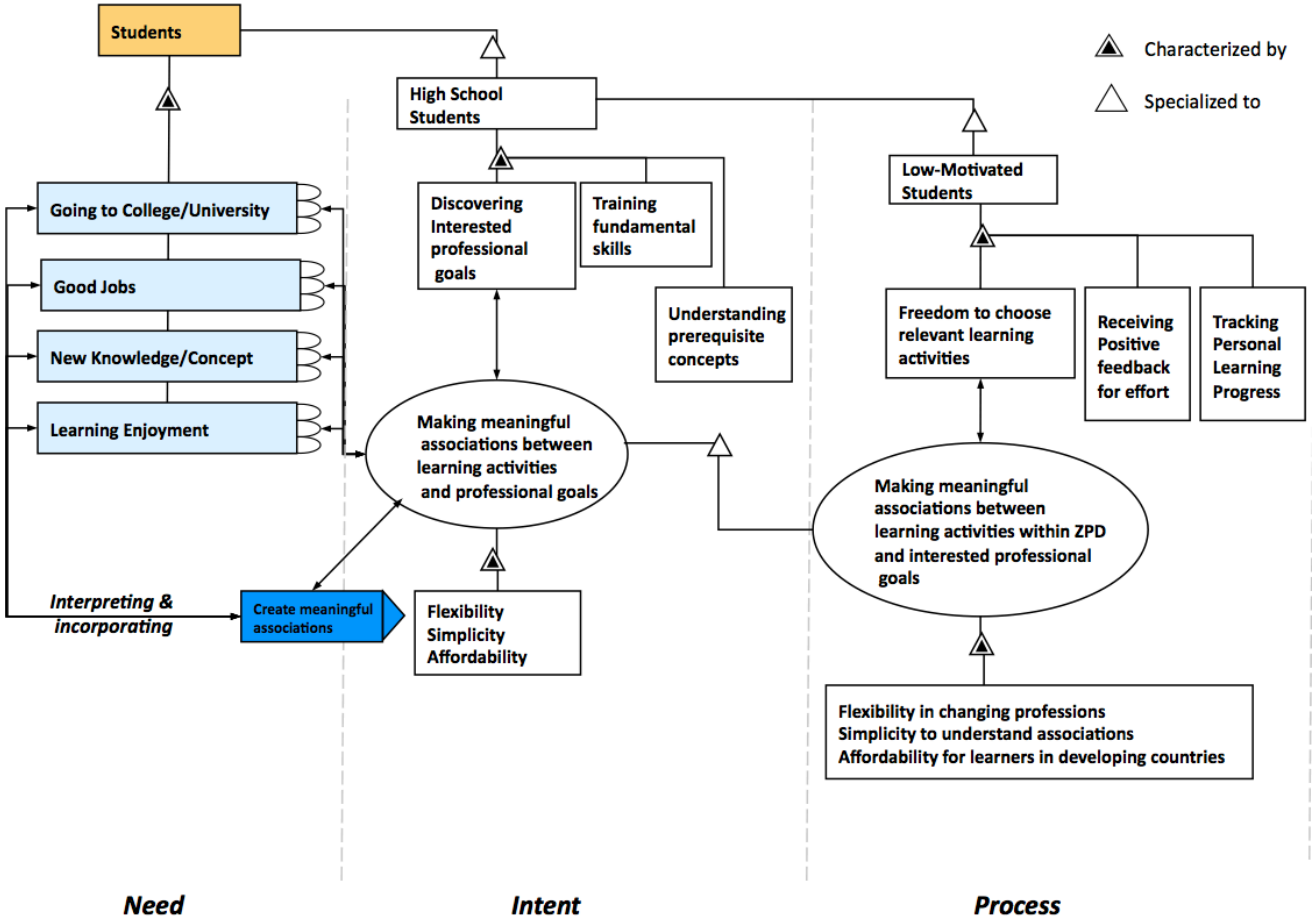


Figure 41: Mapping a System Problem Statement to Object Process Diagram

6.2.5. Descriptive Goals and Prioritization

Along with a clear and attainable system problem statement, the following descriptive goals are documented based on the priority to the success of the proposed design of system architecture. All the descriptive goals are classified into three types of goals:

Critical Goals – the goals that the system architecture **must** meet

- Learning system must sufficiently prepare learners for college and getting jobs
- Learning system must acquire high quality educational resources from accredited education institutions
- Learning system must facilitate the communications (i.e., knowledge, learning activity and feedbacks) between mentors and learners
- Learning system must track learning progress and accomplishments

Important Goals – the goals that the system architecture **should** meet

- Learning system must provide a mentor learner profile (i.e., learning style, historical academic records, competency, background, working experiences)
- Learning system should provide parents a learner progress report

Desirable Goals – the goals that the system architecture **might** meet

- Learning system might take skill development direction from business entities into consideration
- Learning system might train a learner as a skillful professional

6.2.6. Proposed System Architecture Constraints

Although making meaningful associations between professional goals and learning activities within ZPD to enhance intrinsic motivation of high school students in learning will satisfy the primary system goal, a critical descriptive goal of acquiring affordable high-quality educational resources for learners, especially in under-developed countries is not yet met. According to the "Tuition Fees and Student Financial Assistance 2010 Global Year in Review[69]" released in February 2011, students in Pakistan, Thailand and Philippine encountered the largest increases in barriers to education in 2010 because all countries experienced major cuts to student financial assistance. In the same vein, the tuition fees in South Africa at most institutions rose between 9 and 15% while Singapore universities increased their tuition fees ranging from 3 to 10 percent depending on academic programs.

		Student Financial Assistance Policy			
		Decrease in student aid	**No change in student aid**	**Small increase in student aid**	**Significant increase in student aid**
Tuition Fee Policy	**Decrease in tuition**				
	No change in tuition	Pakistan, **Philippines**, Thailand	Argentina, Brazil, Colombia, Egypt, Finland, France, Hong Kong, Indonesia, Israel, Italy, Malaysia, Mexico, Poland, Saudi Arabia, Sweden, Switzerland, Taiwan, Turkey, the UK	**Chile**, China, Germany, India, Japan, Nigeria, Russian Federation, Spain	
	Small increase in tuition	**Netherlands**, Canada (Alberta)	Singapore, South Africa, Ukraine	Some US states, Korea, most Canadian provinces	**Australia**[7]
	Large increase in tuition			Some US states (e.g. California)	Vietnam

Table 28: Changes to Higher Education Affordability in 2010 and 2011 in the G40[6]

[69] Higher Education Strategy Associates. (2010, February). Tuition Fees and Student Financial Assistance 2010 Global Year in Review. Retrieved May 15, 2011 from http://www.higheredstrategy.com/publications/2011/Year_in_Review_2010.pdf

The system design constraint identified in chapter 3 suggested that a good learning system must be designed to help reduce education costs to allow students to afford educational opportunities at their own will.

> *"So, how can we tackle the problem of insufficient access to high-quality teachers and educational resources while also lowering the cost of education to an affordable level?"*

Thanks to four big consecutive initiatives, which provide reusable digital educational content in 1994; open content in 1998; creative commons in 2001; and MIT OpenCourseware in 2001, the open educational content has been pushed forward[70]. It was not until 2002 that the phrase "open educational resource" was coined at a forum held by UNESCO. People who wished to develop together a universal educational resource available for the whole of humanity chose the term "open educational resource" to describe their efforts:

> *"Open Educational Resources are defined as "technology-enabled, open provision of educational resources for consultation, use and adaptation by a community of users for non-commercial purposes. They are typically made freely available over the Web or the Internet. Their principal use is by teachers and educational institutions support course development, but they can also be used directly by students. Open Educational Resources include learning objects such as lecture material, references and readings, simulations, experiments and demonstrations, as well as syllabi, curricula and teachers' guides."*

Khan Academy[71], recently featured by most major news outlets from

[70] Retrieved May 15, 2011 from http://opencontent.org/blog/archives/247
[71] Retrieved May 15, 2011 from http://www.khanacademy.org/about

CNN[72] to National Public Radio, is a not-for-profit organization providing a free world-class educational video to anyone including high school students. This confirms the future trend of the open education resources.

For these reasons, the design of the proposed system architecture is focused toward a computer-based system architecture for an intrinsically motivated learning system to utilize the full advantage of increasing open educational resources as well as to interoperate with other existing non-commercial learning technologies.

6.2.7. Refined System Problem Statement

In order to illustrate the salient associations between selected professional goals and high school learning activities within their ZPD on computer-based systems, the "concept map" appears to be one of the strongest visualization approaches because concept maps have long been used and developed to enhance meaningful learning in the sciences[73]. Since a well-done concept map is usually framed by a specific context of a focus question, the concept map seems superior to another popular approach like a mind map where the branches radiating out from a central picture might not greatly illustrate systematic associations between careers and concepts in knowledge domains. As a consequence, the refined system problem statement became as follow:

> ***"To** enhance high school student's intrinsic motivation in learning; **By** making visually meaningful associations between selected professional goals and high school learning activities within the student's zone of proximal development*

[72] Kaplan, David. (2010, August), *Bill Gates' favorite teacher.* Retrieved May 15, 2011 from http://money.cnn.com/2010/08/23/technology/sal_khan_academy.fortune/index.htm
[73] Retrieved May 15, 2011 from http://en.wikipedia.org/wiki/Concept_mapping

(ZPD); ***Using*** *a self-directed interactive visualization tool;* ***While also*** *offering the ability to provide simplification of understanding associations, flexibility in changing professional goals over time and affordability for learners in developing countries"*

6.2.8. Skills and Knowledge Concepts as Middle Connectors

Making direct associations between professional goals and learning activities in high school could be difficult and expensive because there are countless dissimilar learning activities provided by various high schools around the world. This problem imposes difficulties for making a simplified network of numerous associations, resulting in the introduction of Bloom's taxonomy (a classification of learning objectives within education) and ontology for educational domains[74] as tools to manage the complexity in associating learning activities to professional goals. Figure 42 presents one form of ontology for the domain of algebra[75], which is used to systematically organize diverse concepts in algebra. With existing educational ontologies, learning activities can be managed through ontology-enabled systems.

[74] An ontology is a formal representation of knowledge as a set of concepts within a domain, and the relationships between those concepts

[75] K. Anders Ericsson. (2009). Development of professional expertise : toward measurement of expert performance and design of optimal learning environments. New York, NY. Cambridge University Press.

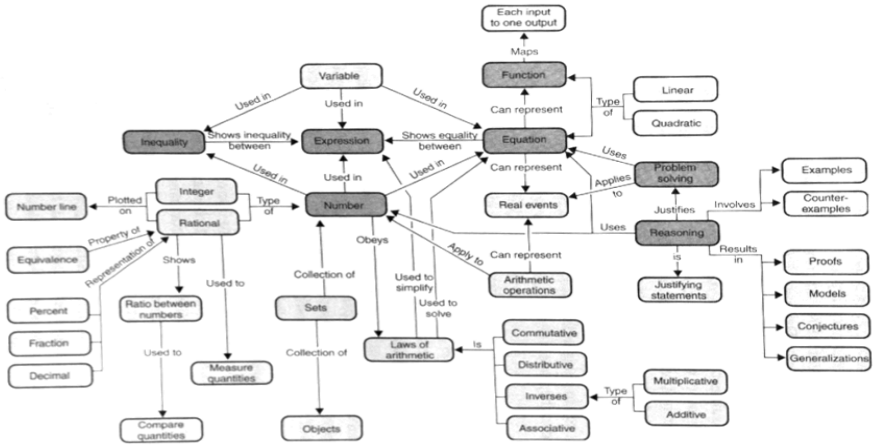


Figure 42: Algebra ontology for Teacher and Student Use (Subsection)

Not only is every learning activity likely to have predefined sets of knowledge and related cognitive skills as its learning objectives, but also most teachers explicitly define these expected sets of the knowledge and cognitive skills in the course descriptions or syllabi. This conventional school administration clearly confirms the immediate practicality of the concept of using "skills" (i.e., identifying, classifying)" and knowledge concept structures in relevant educational ontology as middle connectors between professional goals and learning activities to simplify the complex network between learning activities and professional goals.

To serve as a high-level example, the depiction below shows both how ontology in Mathematics is used to structure the Calculus-related concepts (which link to the associated learning contents on the Internet) and Bloom's taxonomy is employed to classify cognitive skills constructed from relevant concepts. Since some of those cognitive skills are critical to some particular professions (i.e., a scientist might use calculus to formulate a Math model while CEO could use calculus to make a strategic business decision), the skill management systems in

talent management systems can suggest multiple associations among critical skills and professional roles.

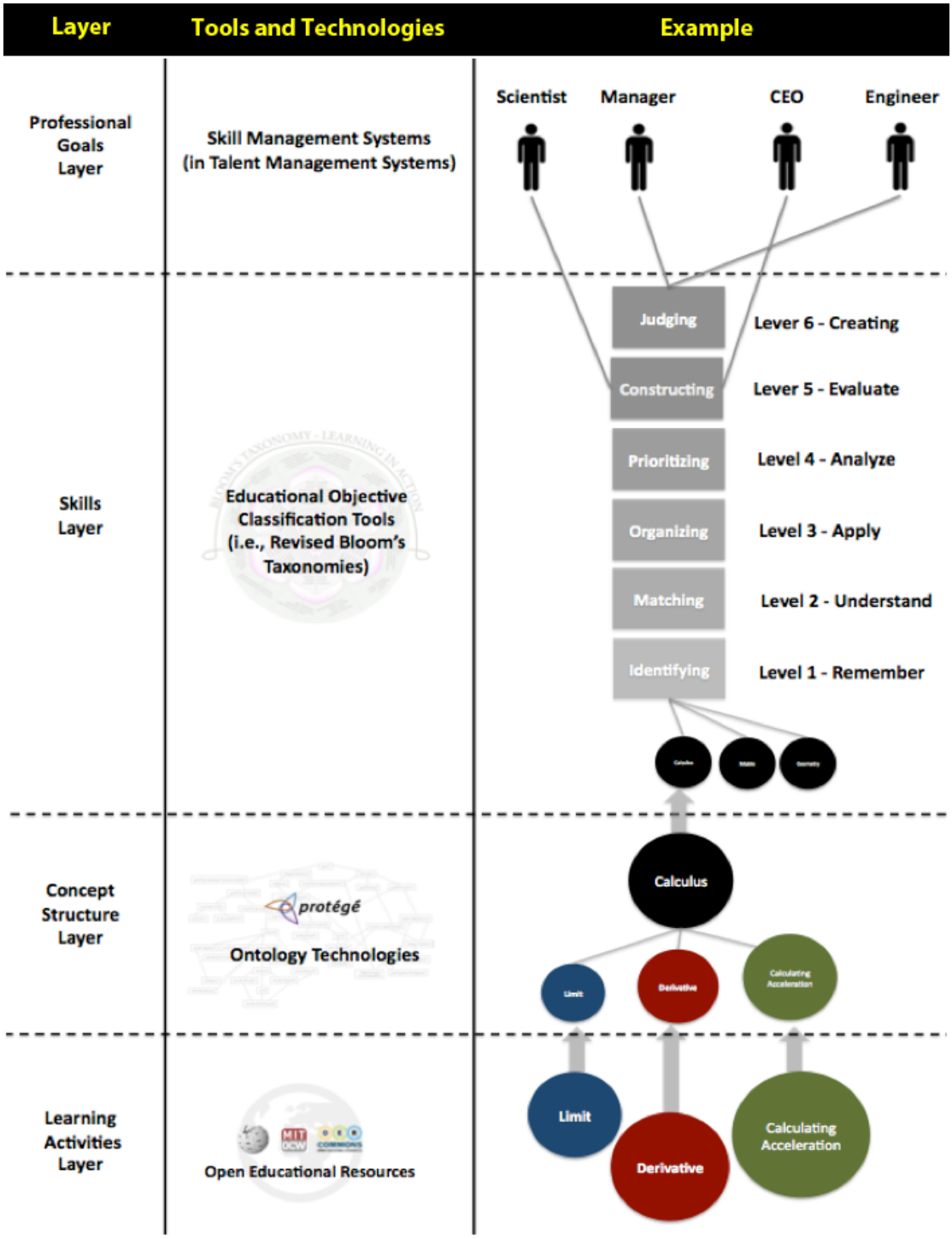


Figure 43: Skill and Concept as Middle Connectors

6.2.9. Bloom's Taxonomy and Beyond

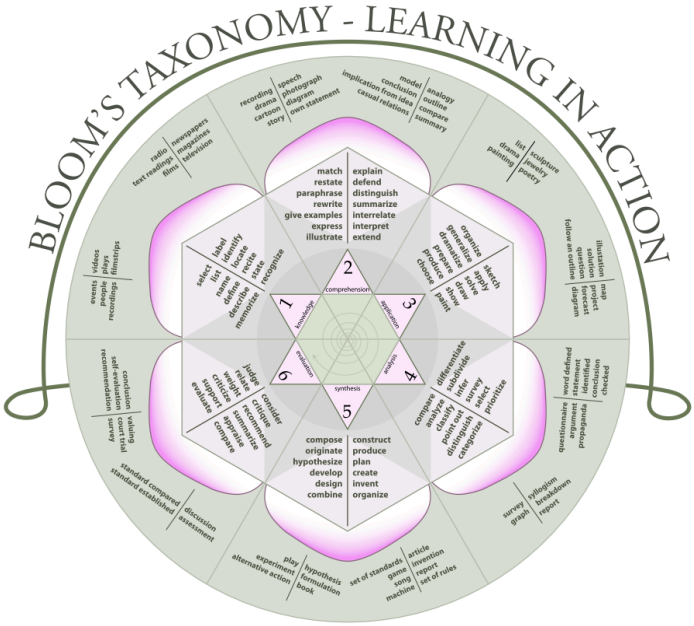


Figure 44: Bloom's Taxonomy[76]

Besides the original Bloom's taxonomy shown in figure 44, the Revised taxonomy of Educational Objectives[77] shown in the table 29 is introduced as a superior classification tool for educators to not only develop a visual representation of a learning unit or a syllabus in a form of a matrix but also facilitate accurate communication across teachers and subject matter experts. The following scenario demonstrates how to use the matrix in classifying educational objectives. If a teacher wants students to explain the consequences of the Parliament Acts for different colonial groups, she could classify and put **this learning objective in the cell B2** because "explain" is the cognitive process number seven in the column two whereas the "consequence" of the Parliament Acts can be referred to generalized statements about Acts after taking effect, which is closest to **Bc. Knowledge of theories, models and structures** in row B.

[76] Retrieved May 15, 2011 from http://upload.wikimedia.org/wikipedia/commons/2/24/Blooms_rose.svg
[77] Amer, A. (2006). Reflections on Bloom's Revised Taxonomy. *Electronic Journal of Research in Educational Psychology 4*(1). 213-230. Retrieved May 15, 2011 from http://www.investigacion-psicopedagogica.org/revista/articulos/8/english/Art_8_94.pdf

Revised Taxonomy of Educational Objectives*

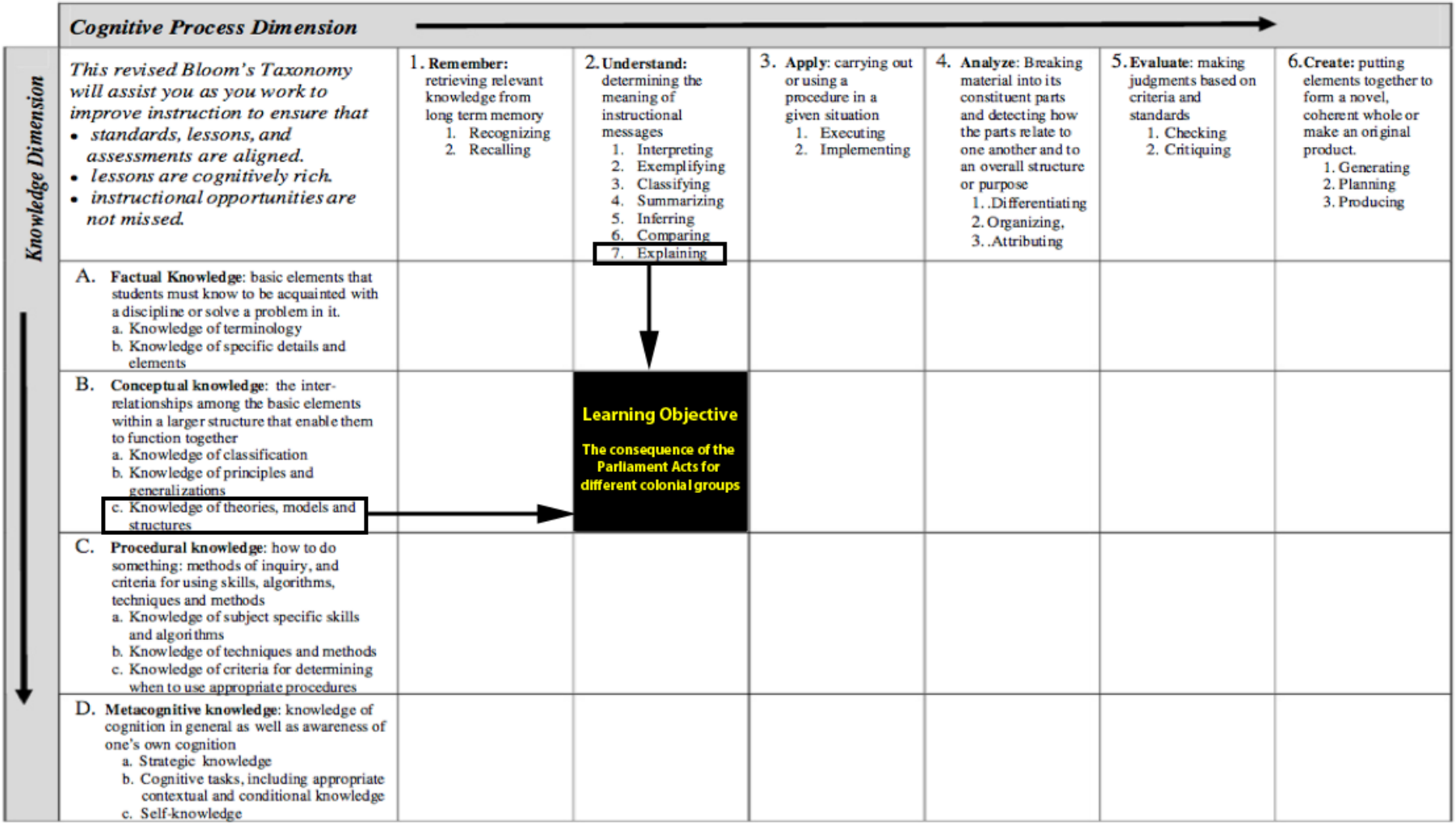


Table 29: Revised Taxonomy of Educational Objectives

6.3. Proposed System Architecture

Although making meaningful associations becomes simple and manageable with the cognitive tools introduced until at this point, a more specific design of system architecture for intrinsically motivated learning systems (IMLS) based on LTSA layer 3 is proposed in this section to serve as a ground for developing learning systems in reality. As shown in the figure below, LTSA layer 3 system components are decomposed into sub-system components in the proposed system architecture for IMLS, which is comparable to the layer 4 of LTSA.

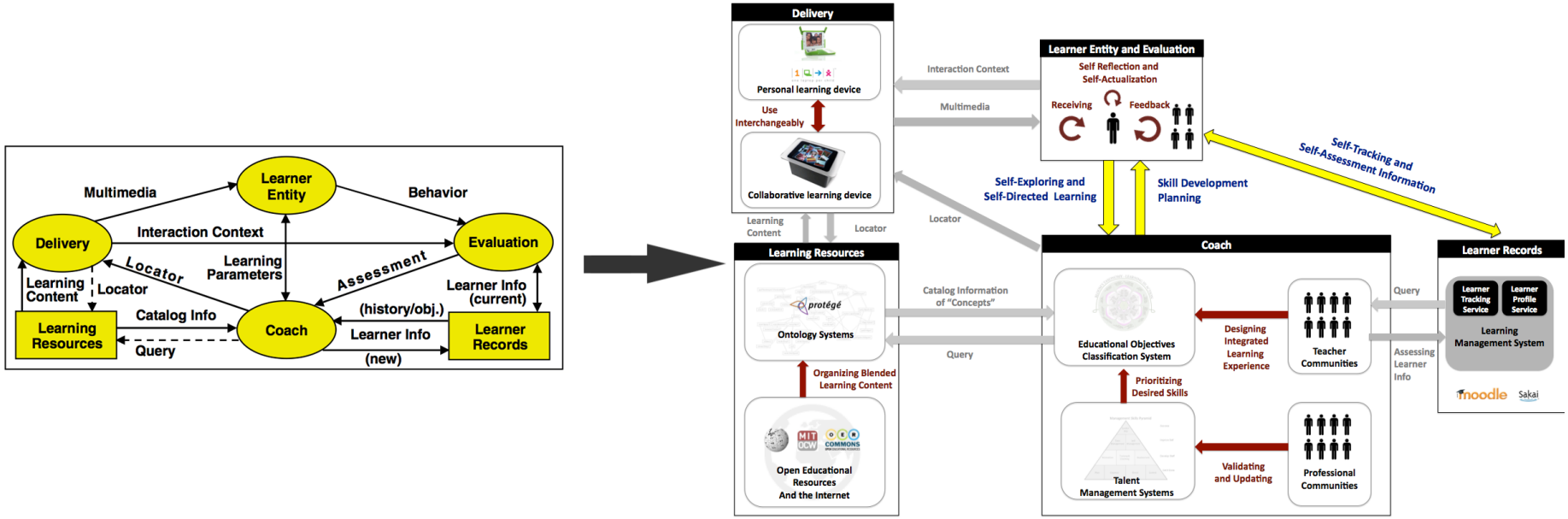


Figure 45: Transforming from LTSA Layer 3 to Proposed System Architecture for Intrinsically Motivated Learning Systems (Comparable to LTSA Layer 4)

The system components of IMLS consists of:

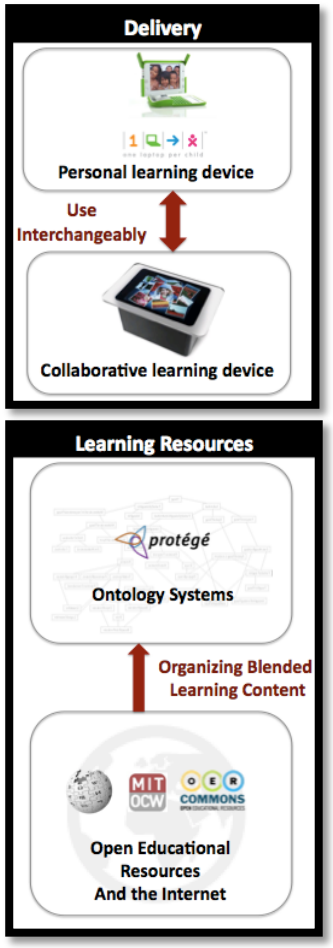


Figure 46: Delivery and Learning Resources Sub-System Components

IMLS Layer Component	LTSA System Component	System Component Description
Personal Learning Device	Delivery	An abstract class representing personal computing devices, which could be used to access learning contents everywhere and on-the-go. This class would promote self-directed mobile learning.
Collaborative Learning Device	Delivery	An abstract class representing collaborative computing devices, which could be for face-to-face collaborative learning (i.e., Microsoft Surface) located at learning facilities (i.e., school, office, home).
Online Education Resources and the Internet	Learning Resources	Links to the education resources, which could be Video clips on YouTube, documents from Wikipedia or even SCROM-compatible learning objects.

Ontology Systems	Learning Resources	An abstract class representing both ontology in educational domains (i.e., Math Ontology[78], Physics Ontology[79] and so on) and ontology-based system, used together as an ontology system. The objective of this class is to categorize blended learning contents and searched for relevant learning concepts.

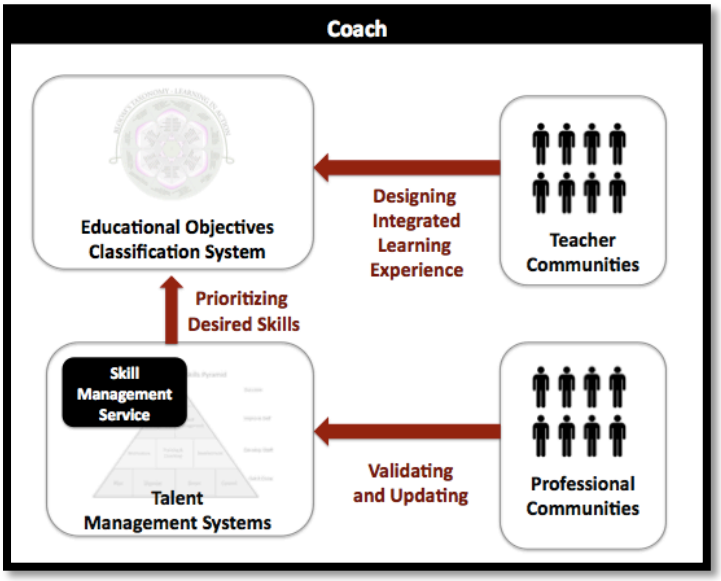


Figure 47: Coach Sub-System Component

IMLS Layer Component	LTSA System Component	System Component Description
Educational Objective Classification Systems	Coach	An abstract class representing classification systems where learning activities are designed and categorized based on their objectives and expected outcomes. The classification is dynamic,

[78] Gruber, T. & Olsen, G. (1994). *An Ontology for Engineering Mathematics.* Retrieve May 15, 2011 from http://www-ksl.stanford.edu/knowledge-sharing/papers/engmath.html
[79] Cook, D. *Ontology of Physics for Biology.* Retrieve May 15, 2011 from http://www.bhi.washington.edu/research/SemBioProcess/OPB.htm

		which depends on the inputs from teaching communities and the alignment with talent management systems from industries.
Talent Management Systems	Coach	An abstract class representing skill management services in generic talent management systems. The systems can suggest what skills are necessary for each professional across industries. The professional communities would be responsible for validating and updating.

Figure 48: Learner Record Sub-System Component

IMLS Layer Component	LTSA System Component	System Component Description
Learner Tracking Service	Learning Management System	An abstract class representing learner-tracking services in generic learning management systems. The services might provide student, grades, test

		score, performance and so on.
Learner Profile Service	Learning Management System	An abstract class representing learner profile services in generic learning management systems. The services provide learners' preference and characteristics.

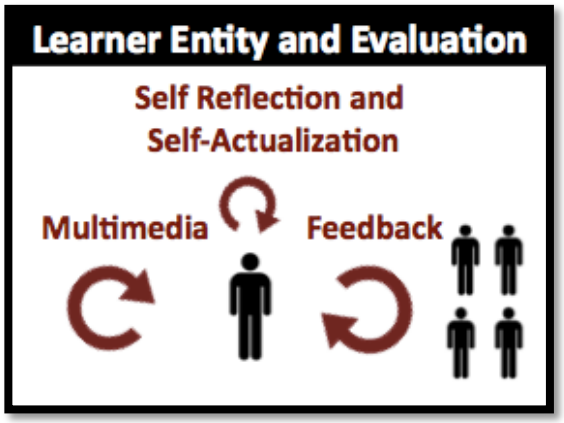


Figure 49: Learner Entity and Evaluation Sub-System Component

IMLS Layer Component	LTSA System Component	System Component Description
Learner	Learner Entity and Evaluation (Merged Learner Entity and Evaluation from LTSA – Layer 3 together)	An abstract class representing a single learner interacting with 3 sources of knowledge: multimedia from learning devices, feedbacks from personal social network and self-reflection from learner himself

6.3.1. System Architecture Interactions

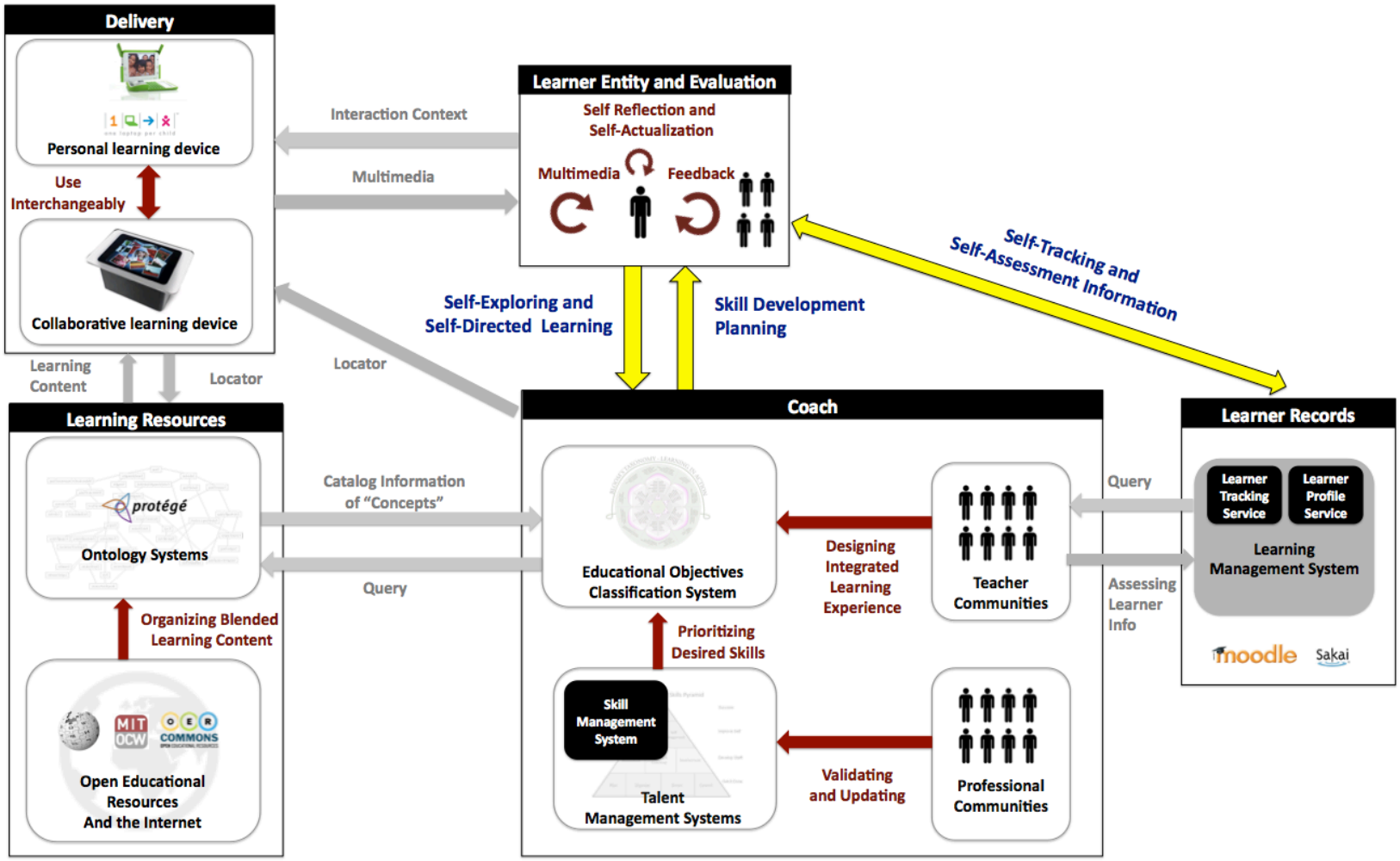


Figure 50: Interactions of Intrinsically Motivated System Architecture

The system interaction of the designed system architecture can start from:

1. A learner defines an immediate professional goal or interest from which personal beliefs gained through self-reflection about the world, forms of feedback (i.e., verbal, body gesture) from his or her personal social network (i.e., friends, parents, peers, teachers) and surrounding multimedia (i.e., document, movie, song) combine to affect the process of definition.
2. The learner begins to explore a learning space on the suggested learning path (or plan) provided by an educational objective classification system according to his defined professional goal or interest. The educational objective classification system received three main inputs:
    - The structure of knowledge recommended by the ontology systems, which provide the learner with the minimum set of prerequisite concepts in order to accomplish the specific concepts tied to his defined professional goal. For example, the leaner wants to learn investing. The professional goal is to master skills of an investor. So, the ontology systems suggest prerequisite concepts in investment to the learner.
    - The desired set of skills for each professional from skill management system in generic talent management systems, which prioritize skills needed for a selected professional goal. The skill management system should be proposed, updated and validated by the professional communities periodically.
    - The “scheme” of learning paths is designed by teaching communities. The scheme can contain several learning paths among which the learner can choose.

These three inputs enable the educational objective classification system to offer the learner with a set of integrated learning paths (or plan), which are available in the accessible learning space where the various learning contents can be directly retrieved from open educational resources and the Internet via URL or indirectly retrieved as learning objects from SCORM-compatible systems.

3. The learner can learn through multimedia on his personal learning devices (i.e., OLPC tablet for students in developing countries or even a mobile phone) and collaborative learning devices at common learning facilities (i.e., schools).

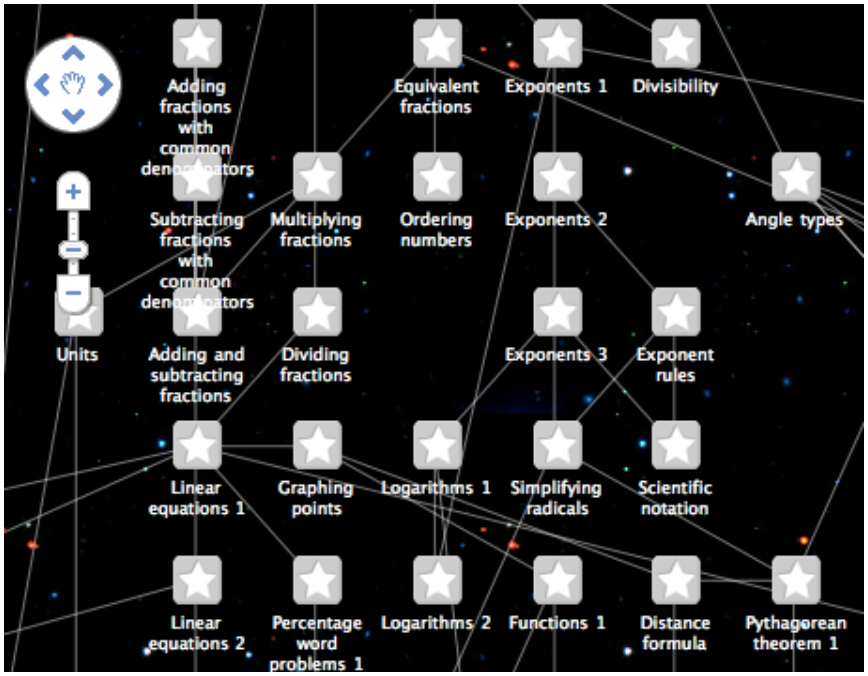


Figure 51: One Possible Visualization of a Learning Space (by Khan's Academy) - Each Box Represents One Concept While Each Line Represents a Learning Path

4. Any given point on the path, the learner can track and assess his or her accomplishments, learning progress, learning preference and competency level. The tracking services and learner profiling services in a generic learning management system should be able to handle these tasks.

There is a wide variety of active research on almost all system components and system interactions in the proposed system architecture for IMLS (i.e., ontology systems for education, learning management systems, talent management systems, educational objective classification systems, learning devices). For this reason, this thesis centers on the other two system interactions in which only a few research projects have been conducted in order to ensure the practicality of using the proposed system architecture as a blueprint for IMLS. Those two interactions are:

- Interaction between learner system and coach system (self-exploring and self-directed learning), and
- Interaction between the learner system and learner records (self-tracking and self-assessment)

The concept development process taught in ESD.34 System Architecture class is used to guide the development of a user interface, which is responsible for main interactions between the learner and other system components. The conceptual design of user interface and the consequent prototype implemented as a proof of concept are presented in the next chapter.

7. Concept Development and Prototyping

Finding an effective visualization approach to delineating meaningful associations between professional goals and high school learning activities is challenging because the heterogeneous mentality of learners leads to an extensive range of dissimilar cognitive interpretations. An inappropriate visualization approach could impose difficulties in extracting meaning from the visual representation of the simplified associations, especially for the first time users. This challenge called for preliminary research on the visualization methods that could offer a preview of vital pieces of informative associations to learners at first sight.

7.1. Concept Exploration

Thanks to the periodic table of visualization methods[80], the visualization approaches are categorized according to their distinctive features such as a group of process visualizations and a group of convergent-thinking visualizations. For that reason, the following desired visualization features are developed as main decision criteria for selecting "fit-in-context" visualization approaches:

- The visualization approach must provide a holistic **overview and detail** of associations between professional goals and high school learning activities in the first place so learners can be aware of most possible associations
- The visualization approach is appropriate for **structure** visualization because the associations between professional goals and learning activities focuses on their structure, not their process

[80] Retrieve May 16, 2011 from http://www.visual-literacy.org/periodic_table/periodic_table.html

- The visualization approach should effectively communicate **qualitative** concepts rather than quantitative concepts, and
- The visualization approach should help develop **convergent** thinking, which promotes critical thinking by reducing complexity through analysis and synthesis

Filtered by the defined decision criteria, the visualization approaches were narrowed down to 6 choices (highlighted in brighter shades) before 3 choices (Parallel Coordinate, Information Lens and Tree Map) were further removed from the list because of their inappropriateness for the current context[81]. As a result, the Graph Pyramid, Cone Tree and Hyperbolic Tree[82] are the only 3 choices selected as applicable concepts to overcome the visualization challenges.

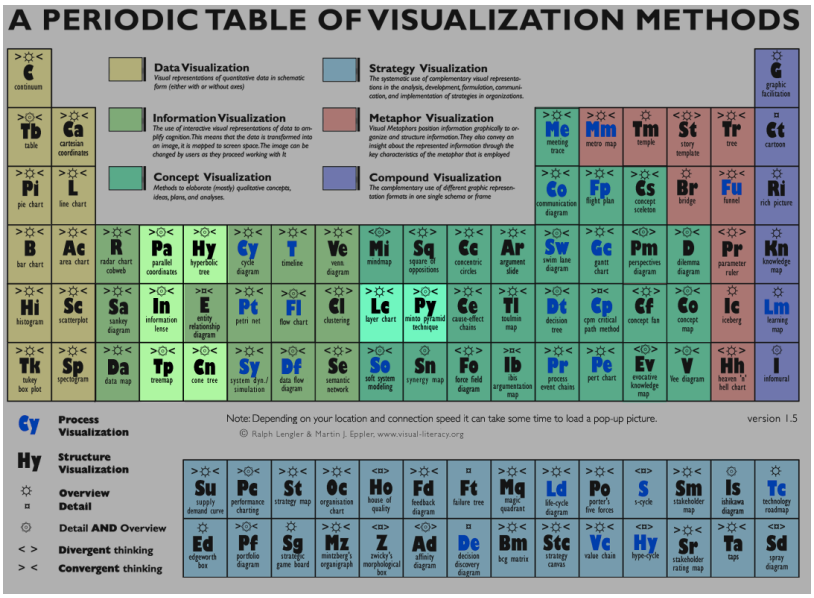


Figure 52: Periodical Table of Visualization Methods

[81] Pa (Parallel Coordinates), In (Information Lenses) and Tp cannot intuitively depict a hierarchical structure. So, these three approaches were removed from the list

[82] Examples are available at http://www.randelshofer.ch/treeviz/ -- Retrieve May 16, 2011 from http://www.randelshofer.ch/treeviz/

The revised system problem statement developed in the chapter 6 and the three visualization concepts selected in this section together lead to the updated object process diagram illustrated in figure below. Each concept is described in detail in the next page.

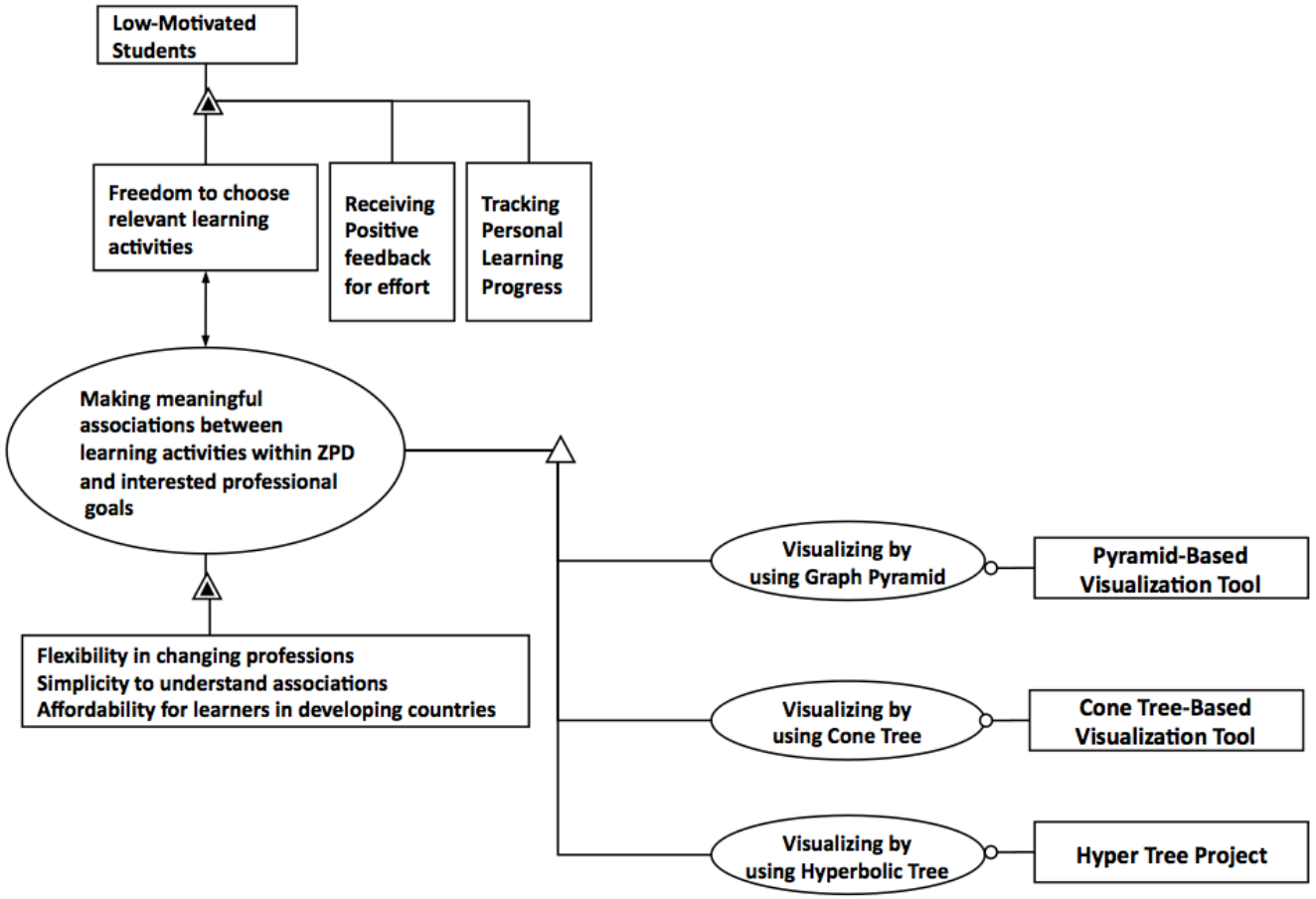


Figure 53: Design Vectors: Visualization Tool for Intrinsically Motivated Learning System

7.1.1. Hyperbolic Tree

A hyperbolic tree was firstly introduced by researchers at Xerox[83]. Since a hyperbolic tree intrinsically has "more room" than Euclidean space, users can see the entire tree structure at once. Together with Poincare disk model of hyperbolic geometry, a fish-eye lens view of the plane can emphasize nodes, which are in current focus, while displaying other nodes further out of focus closer to the boundary of the disk. It is obvious that this visualization approach can meet the defined requirements as listed in the main decision criteria, which are:

- The tree structure is very appropriate for structure data and qualitative data
- The fish-eye lens view provides a holistic view of the entire tree and cognitively supports convergent thinking.

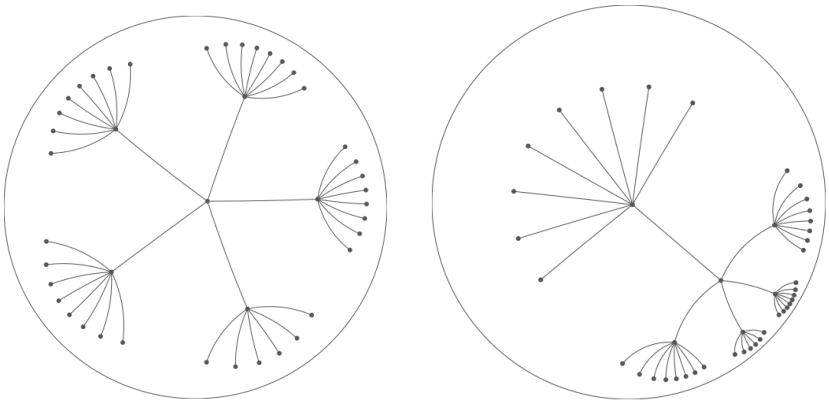


Figure 54: The Display of Hyperbolic Trees When Different Nodes are in Focus[84]

7.1.2. Graph Pyramid

Graph pyramids (synonymous with image pyramids) offer a way to visualize the hierarchies of graphs and the linkage between consecutive graph

[83] Spring, T. (1999). Inxight Shakes the Tree of Knowledge. *PCWorld.* Retrieve May 16, 2011 from http://www.pcworld.com/article/10473/inxight_shakes_the_tree_of_knowledge.html
[84] Snapshot was taken from the JavaScript (Canvas) Hyperbolic Browser – Retrieve May 16, 2011 from http://hypertree.woot.com.ar/

levels, which satisfies the defined requirements of appropriateness for presenting a holistic view of structured data and qualitative data. Besides, the visualization of the whole graph pyramid is well suited for navigation purposes[85], enhancing the convergent thinking of first time users.

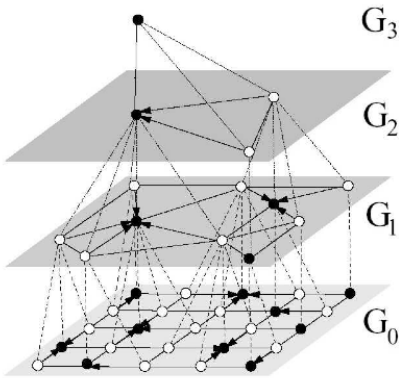


Figure 55: A Small Graph Pyramid Based on a 5x5 Pixel Image

While entire information can be presented in this hierarchical structure in which each level represents a homogeneous group of information (i.e., a level of concept, a level of skills), the connections between levels can be used to present meaningful associations between any two heterogeneous groups of information (i.e., associations between professional goals and skills).

7.1.3. Cone Tree

The cone tree is a three-dimensional representation of hierarchical information to maximize effective use of available screen space and enable visualization of the whole information structure[86]. The root of the tree is located at the apex of the cone while all its children are arranged around the circular base of the cone in 3D. For the interactive applications, any node can be brought to the

[85] Karren, A. (2006). *Interactive Visualization of Graph Pyramids*. Retrieved May 16, 2011 from http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.60.7885
[86] Robertson, G., Mackinlay, J. & Card, S. (1991). *Cone Trees: Animated 3D Visualizations of Hierarchical Information*. Retrieve May 16, 2011 from http://www2.parc.com/istl/groups/uir/publications/items/UIR-1991-06-Robertson-CHI91-Cone.pdf

front by clicking on it and rotating the tree. Also, each cone can reduce its transparency so the cone can be still perceived and does not prevent users to view other cones behind it.

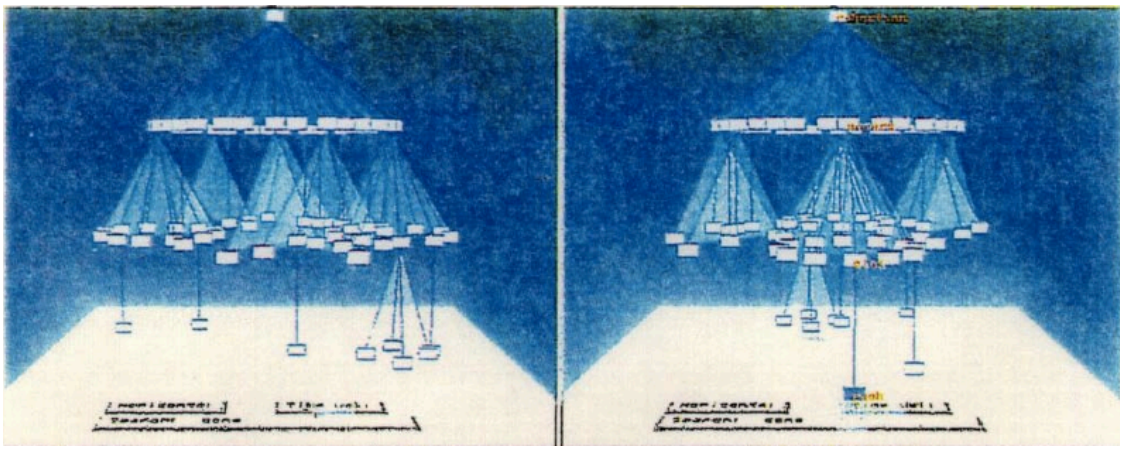


Figure 56: Layout of a Simple Cone Tree Before and After Selection

7.2. Conceptual Design Space

Since all selected visualization concepts can be blended to intuitively delineate the complicated associations between professional goals and high school learning activities, a high-level morphological matrix comes into play in representing the comprehensive view of the possible design space.

Design Function	Design Option		
Delineating the holistic network	Hyperbolic Tree	**Graph** **Pyramid**	Cone Tree
Delineating associations between professional goals and their corresponding skills	Hyperbolic Tree	**Graph** **Pyramid**	Cone Tree

Delineating associations between skills and their corresponding concepts	Hyperbolic Tree	**Graph Pyramid**	Cone Tree
Concepts within a encapsulated bigger concept (i.e., a concept of Calculus can contain derivatives, limit, etc.,)	**Hyperbolic Tree**	Graph Pyramid	Cone Tree

Table 30: Morphological Matrix

As shown in the morphological matrix, "**Graph Pyramid"** is selected to provide the first impression of the whole network because the pyramid shape imposes a sense of "developmental hierarchy" starting from the bottom to the top. Like a great pyramid, which must have a strong fundamental base, a successful professional must have a strong understanding of fundamental knowledge before a knowledge-related skill set can be developed. Once the necessary skill set for the professional is developed and improved, the overall quality of that professional increases accordingly, resulting in the higher success of that profession and community in overall. Although the "**Cone Tree**" visualization approach can also provide the comparable presentation as the "Graph Pyramid" does, the Graph Pyramid approach offers greater flexibility in arranging a variety of associations between any two layers than the Cone Tree visualization approach. For that reason, the Graph Pyramid is a more favorable representation than the Cone Tree. Furthermore, to show concepts structured by a given ontology, the Hyperbolic Tree appears to be a promising visualization approach because it directs user's attention to the center of the space where the node in focus is located.

7.3. Conceptual Design

The network of Profession-Skill-Concept (PSC) shown in the figure below is developed as a conceptual framework to illustrate associations between the current state of students and the desired future state represented by various choices of professions (or roles in a society). The skill layer separates a current student's states to a desired future student's state.

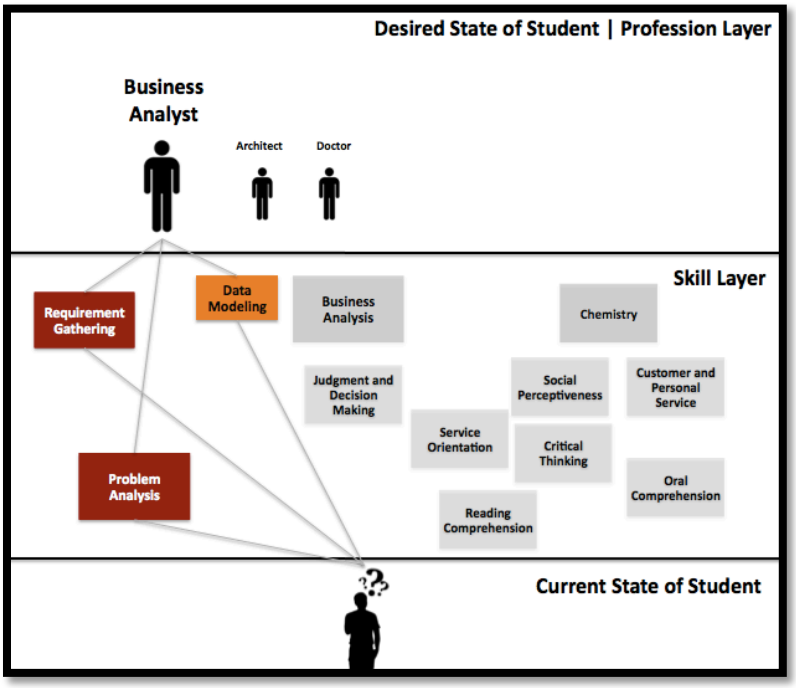


Figure 57: Conceptual Design of PSC Network - Step 1 (Skill Set)

For a student who can pin down what his professional immediate goal is, he can then explore skills that would transforms him from his current state to his desired state (his selected professions). With this conceptual design, the students who are uncertain about their future desires can choose multiple professions at once. The common skills needed for the selected professions will be highlighted with hotter-tone colors while the less relevant skills will be highlighted in cooler-tone colors. If the student targets a profession with a higher rank in a corporate hierarchy, the color of highlighted skills will change toward hot-tone colors as to

reflect the higher competency level needed for those skills to achieve higher-level positions. (i.e., the competency level of "decision making" skill for a business analyst is less than that of a CEO). Besides, it is interesting to note that the desired state of a student could change over time when the student receives more information about the world as well as experiencing changes in personal values over a particular time span. Once the student finds out what skills he should develop for his selected profession(s), he can investigate what relevant knowledge concepts exist across domains (i.e., Science, Math, Art, etc.,) contributing to the development of those necessary skills. Each concept can link to the corresponding learning activities or learning contents.

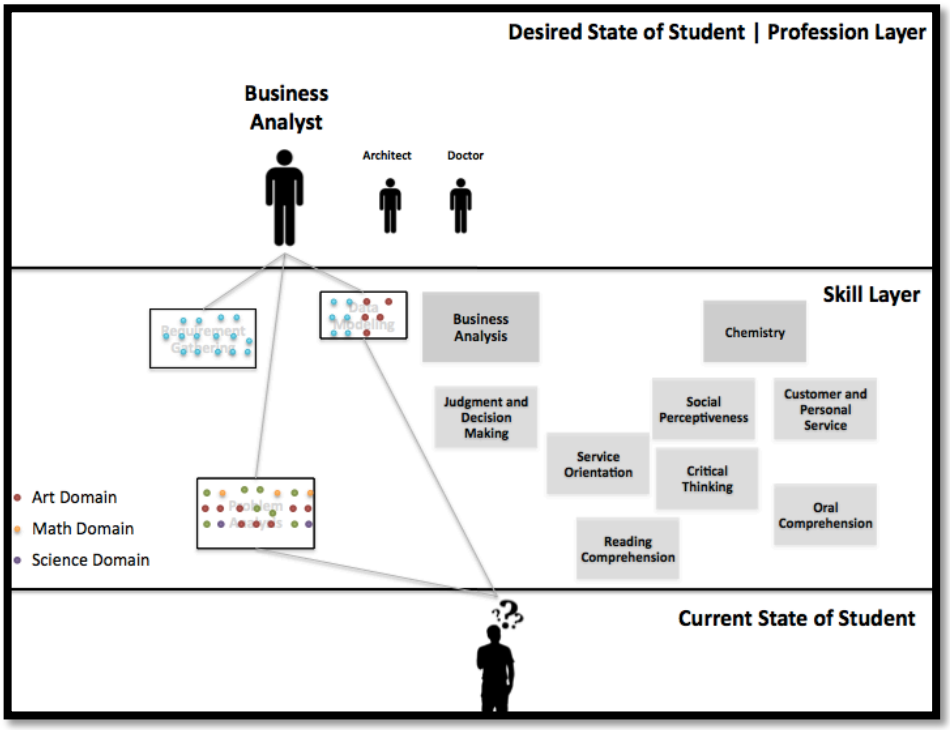


Figure 58: Conceptual Design of PSC Network - Step 2 (Concepts)

With this conceptual design, a student can gain greater exposure to the associations between learning activities and a selected profession. To create relatively accurate associations, the following questions must be answered:

- **What skills should be listed in the skill layer?**

Skills in the skill layer should be the **transferable skills** because the transferable skills are the skills and abilities that are applicable to what a learner could use in his next job or profession[87]. Using a set of transferable skills gives greater flexibility for a learner who might consider changing his desired state over time.

- **What knowledge concepts should be listed in the concept layer?**

As this thesis focuses on high school students, the concepts listed in the concept layer should comprise concepts being taught in the high schools' curriculum. Unfortunately, the prototype will concentrate only on mathematical concepts taught at the high school level due to the limited thesis timeline.

- **How to construct the associations between skills and knowledge concepts and the associations between professions and skills?**

Although the associations between professions and skills can be retrieved from talent management systems[88], most associations between skills and knowledge concepts are tacit knowledge rather than explicit knowledge. For this reason, two online questionnaires are designed and developed to help respondent professionals externalize tacit knowledge regarding such associations. The online questionnaires used for data collection process are shown in the appendix A.

[87] Retrieved May 16, 2011 from http://www.leadingorgsolutions.com/forms/transferable_skills.pdf
[88] Because accessing corporate management systems could impose risks to corporations, online questionnaires are used as a tool to collect the data regarding associations for the prototype instead.

Based on the updated object process diagram presented earlier, the full object process diagram (OPD) for the intrinsically motivated learning system prototype is shown below. The PSC network is a specific form of possible computer-based network visualization tools, which satisfies the process of "making meaningful associations".

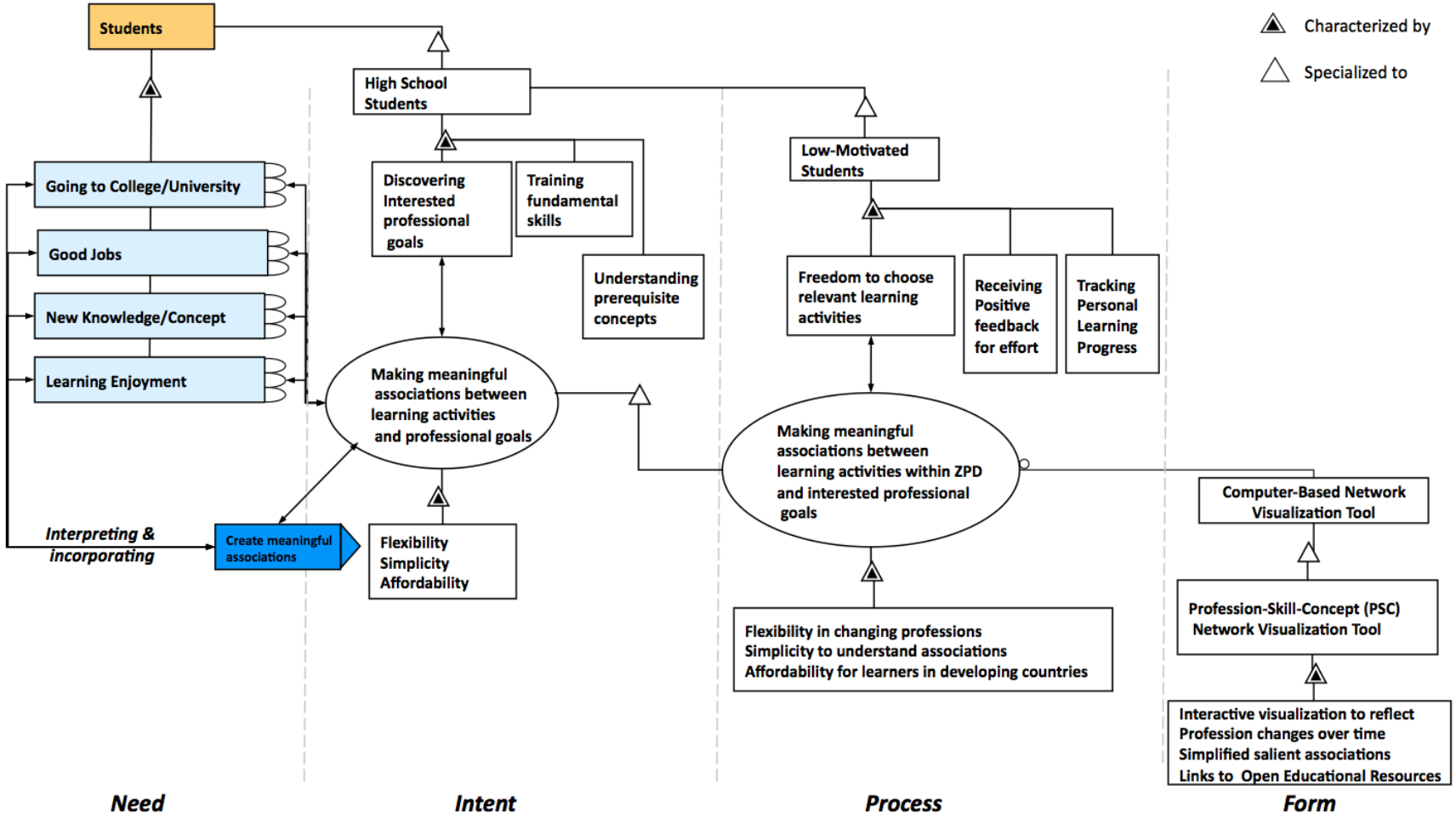


Figure 59: Object Process Diagram for PSC Visualization Tool

7.4. Prototyping

According to the conceptual design, Flash™ technology is chosen to implement the prototype because the technology makes rapid prototyping simple but extremely powerful in term of multimedia and responsive interaction[89]. The technology not only supports the development of highly interactive applications but also introduces an easy way to integrate various formats of VDO contents into the designed prototype. This appealing feature provides seamlessly integrated experience for the self-exploring interaction and the self-assessment interaction, which are the most important parts to ensure the practicality of the proposed system architecture in chapter 6.

7.4.1. Self-Exploring Interaction

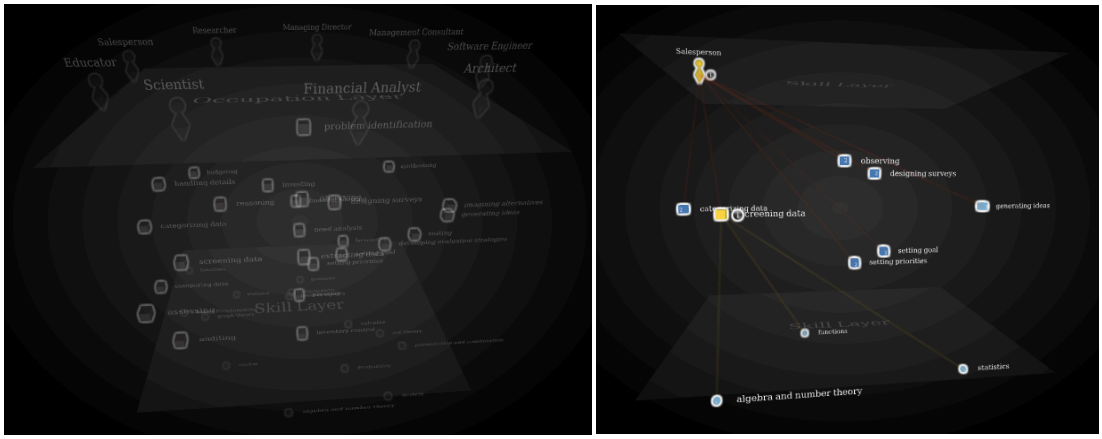


Figure 60: Prototype Graphic User Interface

The snapshot on the left in figure 60 shows a holistic PCS network in which learners can see in the first place. The displaying components consist of professions, skills, and concepts. Professions are represented with human-like objects for quick recognition. Skills are represented with cubes to impose a sense of "skills as building

[89] Fierlinger, P. (2009). Fake It Till You Make It: Rapid Prototyping Using Flash. Retrieved May 16, 2011 from http://www.web2expo.com/webexsf2009/public/schedule/detail/8860

blocks" while concepts are represented with spheres to give a sense of "self-contained" concepts. The associations of an object will appear only if a learner clicks on the object of interest, which turns the selected object color to yellow as shown in the right snapshot in figure 60. Based on the concept of the Pyramid Graph, the learner can start expanding from the top (profession layer) down to bottom (concept layer) or can start stemming from the bottom to the top. This holistic view allows the learner to explore any components that might be of interest without order. In other words, learners can explore professions that are of interest first if they know what professions they want to pursue or they can explore concepts that they already mastered to identify high-potential successful professions.

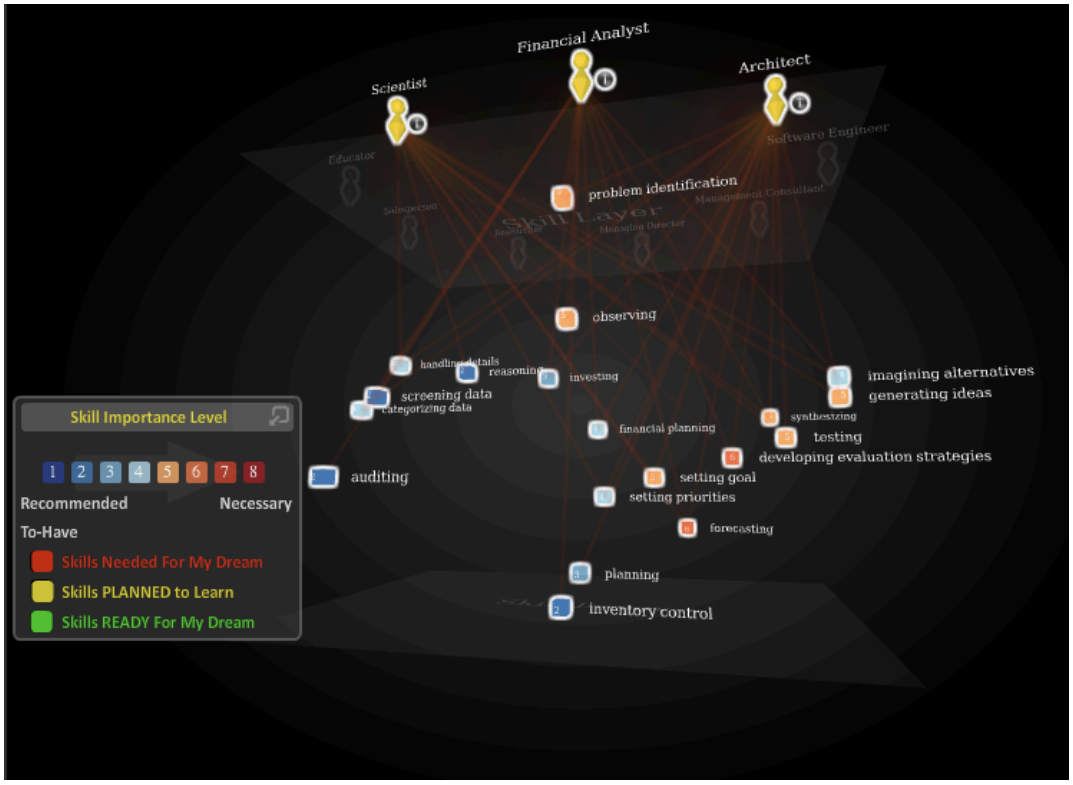


Figure 61: Object Color as an Indicator of the Object's Importance - Step 1

As shown in the figure 61, a learner might be interested in becoming a scientist, a financial analyst or an architect, so he or she clicked on the icons representing those

professions, turning those objects to yellow. The prototype engine then painted skills with the spectrum of different colors from cool tone to hot tone. Different colors of objects indicate the importance of their own. The red-color cube represents the most critical skills needed for the three selected professions (i.e., skill in developing evolutional strategies appear important for financial analysts or scientists) while the dark-blue-color cube represents "recommended-to-have" skills for the three selected professions. This exploration process will allow a leaner to explore further the critical skills. By selecting those critical skills, the relevant concepts contributing to the skill development will be painted with different colors to show their importance, as well.

Figure 62: Object Color as an Indicator of the Object's Importance - Step 2

As shown in the figure 62, the concepts of "probability" and "function" (presenting with red spheres) in high school Mathematics more significantly develop a skill in "developing evaluation strategies", a skill in "forecasting" and a skill in "testing" (presenting with yellow cubes) than other relevant concepts.

7.4.2. Self-Assessment Interaction

Although the scope of the current prototype engine does not provide the links to any standard tests or adaptive tests, which are typically used in the assessment process, the learner can track his progress on skill development by clicking at the concepts he deems he fully understands in a considering time period.

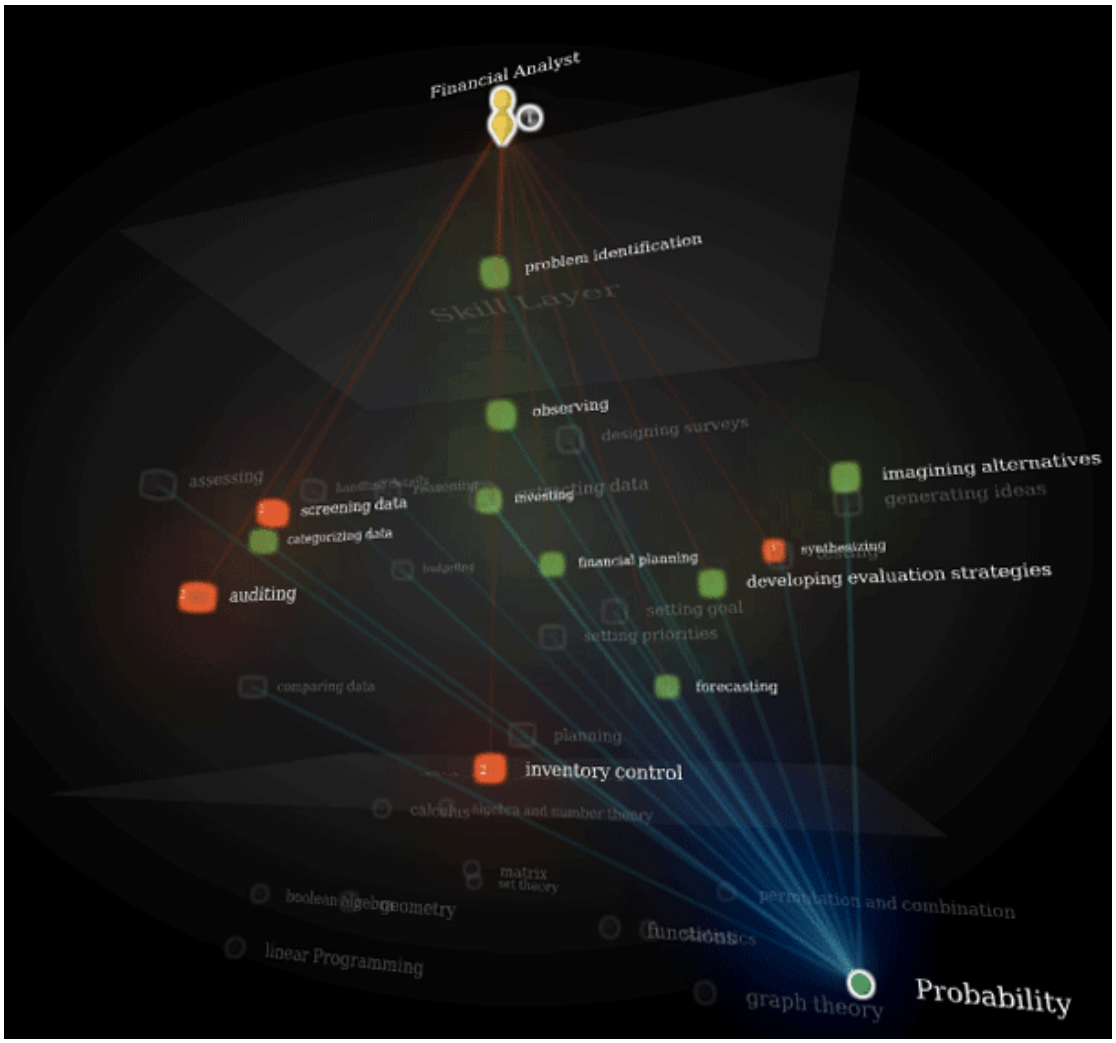


Figure 63: Tracking Skill Development

As shown in the figure 63, the learner is interested in becoming a financial analyst and he believes he has good understanding of probability. As soon as he selects the sphere representing the concept of probability, the prototype engine will calculate and paint skills with two colors. The green cubes represents skills that are considered

"good enough" for the selected profession(s) while the red cubes represents the skills that require some improvements.

7.4.3. Prototype Additional Features

Sorting by importance in 2D: Learners can sort desired professions by approximate success rates or sort skills and/or concepts by importance to recognize what professions, skills or concepts they should focus on. For example, if a learner wants to be either an educator or a financial analyst, he or she notices that problem identification, auditing, forecasting and developing evaluation strategies are more important skills than others. By selecting these skills, the learner subsequently realizes that statistics, functions, probability and linear programming are critical preparation for developing the skills of forecasting and evaluation strategies.

Figure 64: Sorting by Importance in 2D

Profession Overview Information and Role Model Videos: Learners can read detailed information about the selected profession. They can also watch videos of interesting role models in that particular profession to understand how the role models became successful in society.

Figure 65: Professional Overview Information and Role Model Videos

Learning plan and timeline: Learners can command the prototype to automatically generate a learning plan and learning timeline based on the skills selected to develop and number of hours planned to spend for learning activities each day. The learning activities that can contribute the most to developing skills will be listed earlier than the lower-contributing learning activities.

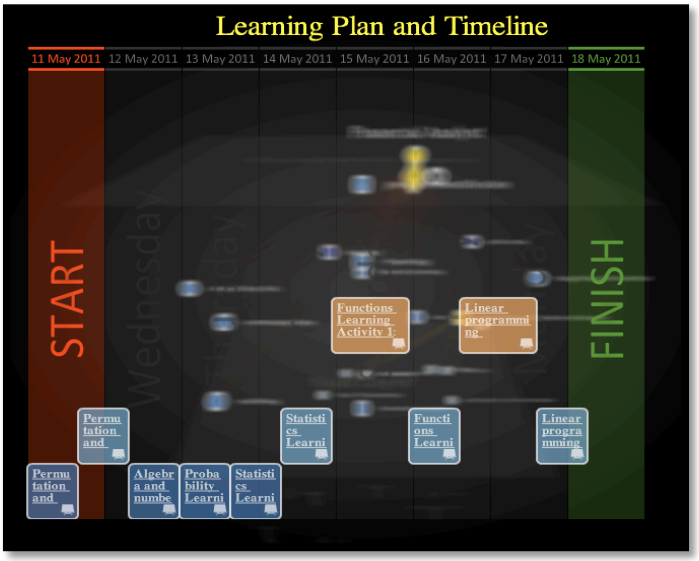


Figure 66: Learning Plan and Timeline

8. Questionnaire Design and Data Analysis

Four sets of online questionnaires were created as an instrument to collect necessary data for this thesis. The purpose of the first two sets was to gather up-to-date professional opinions across selected professions for creating dynamic associations required by the prototype while the last two sets are specifically designed for validating the defined hypotheses.

8.1. Questionnaires for Creating Dynamic Associations

The first two sets of the online questionnaires consist of a questionnaire identifying the associations between professions and skills, and a questionnaire identifying the associations between skills and concepts.

Questionnaire	Objective	Target Respondent
1. Professions and skills associations	To reveal associations between professions and corresponding skills needed for professional activities.	Ordinary workers, knowledge workers in organizations
2. Skills and concepts associations	To identify associations between skills and concepts contributing to those skills	Students in undergraduate degrees and graduate degrees, professors and selected subject matter experts

Table 31: Two Types of Online Questionnaires Used for Creating Dynamic Associations

While the online questionnaire identifying the associations between professions and skills was distributed to random professionals, another online questionnaire identifying the associations between concepts and skills was distributed to selective groups of professionals and to students in leading universities to heighten the data reliability because inaccurate data associations between skills and concepts can give distorted impressions to participating students. The templates of the first two questionnaires are included in appendix A.

8.1.1. Design Rationale of Questionnaire (Professions and Skills)

Without an authorized access to the corporate talent management systems, data regarding the associations between professions and skills from deliberate judgments of real professionals is used as an alternative for the prototype. There are two reasons why opinions from real professionals are acceptably valid. First, every professional should know best what skills he should *currently* possess for his profession. Second, every professional tends to know what concepts they *really* use at work. For these reasons, using deliberate judgments of real professionals not only provides the acceptably practical data (not theoretical data) regarding skills needed for each profession but also introduces the up-to-date data of ever-changing associations over a considering time period. The questionnaire comprises 11 demographic questions such as age, personal values, job title, job functions, etc. and about 80 questions identifying associations between professions and skills. Participating professionals are expected to rate the importance of each skill on a four-point Likert scale. A sample question identifying associations is shown in the figure below.

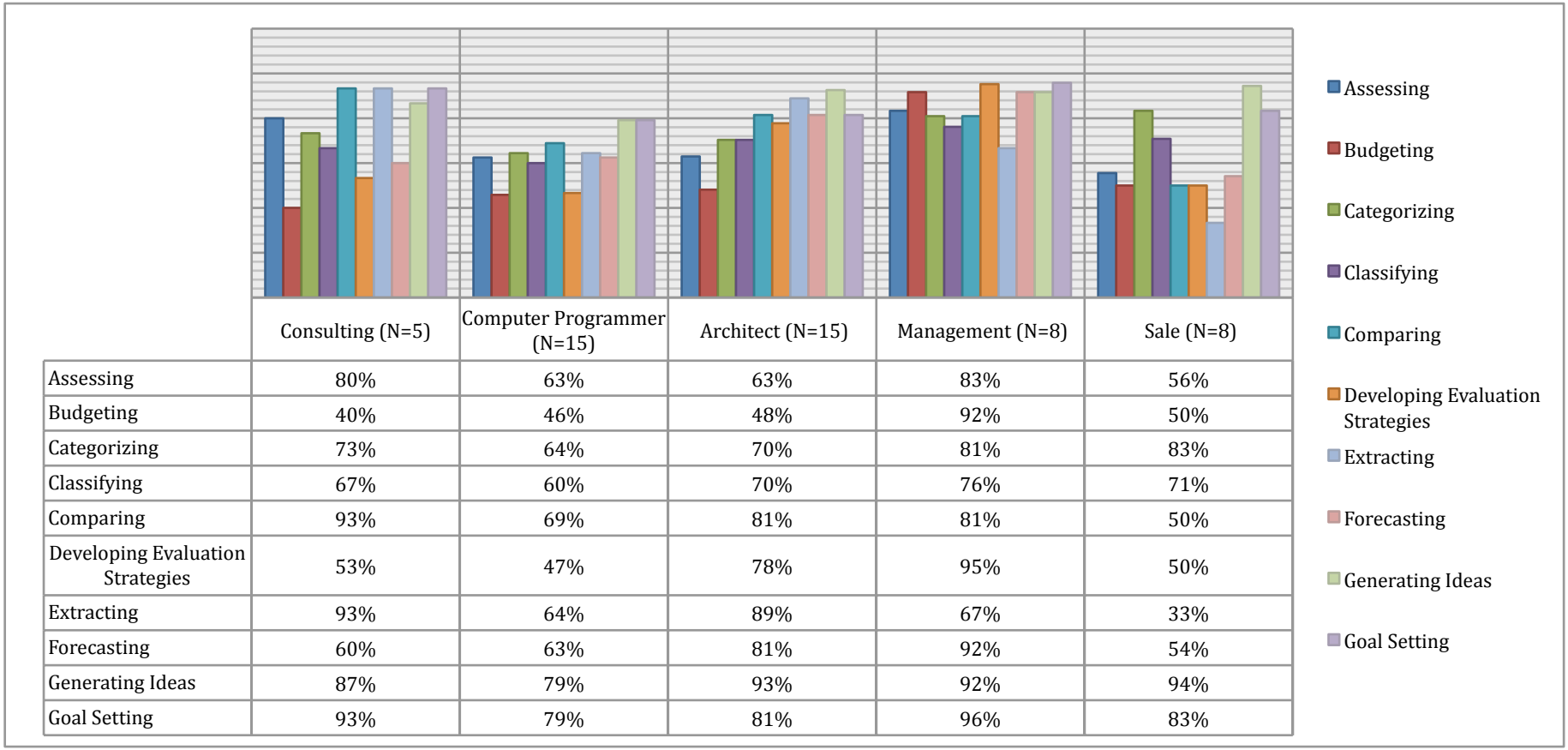
17. How necessary are these ANALYTICAL skills for your job? / ความสามารถทางการวิเคราะห์เหล่านี้มีความสำคัญมากน้อยเพียงใดต่องานของคุณ? *

	Always Need / ขาดความสามารถนี้ไม่ได้	Substantially Need / เป็นความสามารถสำคัญต่องาน	Somewhat Need / ใช้ความสามารถนี้บ้าง	No Need / ไม่จำเป็นต้องใช้ความสามารถนี้
Need Analysis / การวิเคราะห์ความต้องการ *	○	○	○	○
Designing Surveys / การออกแบบแบบสอบถามเพื่อใช้เก็บข้อมูล *	○	○	○	○
Inquiring / การสอบถามหาข้อมูล *	○	○	○	○
Interviewing / การสัมภาษณ์หาข้อมูลจากบุคคล *	○	○	○	○
Observing / การสังเกตุข้อมูลรอบข้าง *	○	○	○	○
Compiling Information / การรวบรวมข้อมูล *	○	○	○	○
Comparing / การเปรียบเทียบข้อมูล *	○	○	○	○
Categorizing / การจัดเป็นกลุ่ม หมวดหมู่ของข้อมูล *	○	○	○	○
Classifying / การรู้จักระบุและแยกแยะข้อมูล เช่น แยกขาวออกจากดำ *	○	○	○	○

Table 32: Sample Questions Regarding Associations Between Skills and Professions[90]

[90] The online questionnaire is presented in Thai and English language to support the mixed groups of respondents.

8.1.2. Data Analysis of Questionnaire (Professions and Skills)



	Consulting (N=5)	Computer Programmer (N=15)	Architect (N=15)	Management (N=8)	Sale (N=8)
Assessing	80%	63%	63%	83%	56%
Budgeting	40%	46%	48%	92%	50%
Categorizing	73%	64%	70%	81%	83%
Classifying	67%	60%	70%	76%	71%
Comparing	93%	69%	81%	81%	50%
Developing Evaluation Strategies	53%	47%	78%	95%	50%
Extracting	93%	64%	89%	67%	33%
Forecasting	60%	63%	81%	92%	54%
Generating Ideas	87%	79%	93%	92%	94%
Goal Setting	93%	79%	81%	96%	83%

Figure 67: Questionnaire Result in Matrix Between Selected Skills and Selected Professions

Based on the questionnaire result (N=124, across all professions), participating professionals could be categorized into the following groups: consultant, management, researcher, salesperson, educators, administrator, scientist, financial analyst and architect.

In the table above, the matrix associating selected skills and selected professions is presented. The average normalized skill importance of the selected professions is converted into percentages for simplification in comparison. For example, management deemed the skill of developing evaluation strategies (95%) is more important than the skill of extracting data (67%). Hence, the higher percentage the skill importance is, the more critical the skill to the corresponding profession. Also, the matrix allows us to compare skill importance among professions. For instance, most skills in the list are more critical to professional managements and management consultants (as successful management or consultants needs multiple skills) than salespersons or computer programmers.

8.1.3. Design Rationale of Questionnaire (Skills and Concepts)

Another set of online questionnaires used for creating dynamic associations is the questionnaire identifying the associations between concepts and skills. Because it is quite difficult for most professionals to identify the associations between skills and concepts, this online questionnaire was selectively distributed to a group of students of top-performing universities (i.e., Thai students at MIT and Stanford) and experienced professionals (i.e., a student group of MIT SDM program) to ensure the relatively acceptable accuracy of the associations. Participating respondents were expected to indicate the subtle associations between particular Math concepts and skills. A sample question of this questionnaire is shown in the figure below.

33. Can these knowledge concepts help you do the following activities better (i.e., faster, more easily, more accurately)?

- Check the box if yes
- Leave it unchecked if no (including **not applicable)**

You can interpret the first checkbox as "the concepts in **Algebra and Number Theory** help me do **Problem Identification** more easily or accurately".

	Problem Identification	Handling Details	Generating Ideas	Setting Goal	Setting Priorities	Planning	Budgeting	Auditing	Financial Planning	Investing	Inventory Control	Assessing	Forecasting
Algebra and Number Theory	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Permutation and Combination *	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Probability *	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Statistics *	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Functions *	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Linear Programming *	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Trigonometry *	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Geometry *	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Matrix *	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Vector *	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Set Theory *	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Boolean Algebra (Logic) *	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Graph Theory *	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Calculus *	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Table 33: Sample Questions Regarding Associations Between Skills and Concepts

8.1.4. Data Analysis of Questionnaire (Skills and Concepts)

According to the questionnaire result (N=27), the associations between skills and concepts are shown in the radar chart below. Apparently, statistics (purple) is the most outstanding contributor to development of various skills while probability (light green), set theory (aqua) and linear programming (orange) are among important concepts contributing to the transferable skill development.

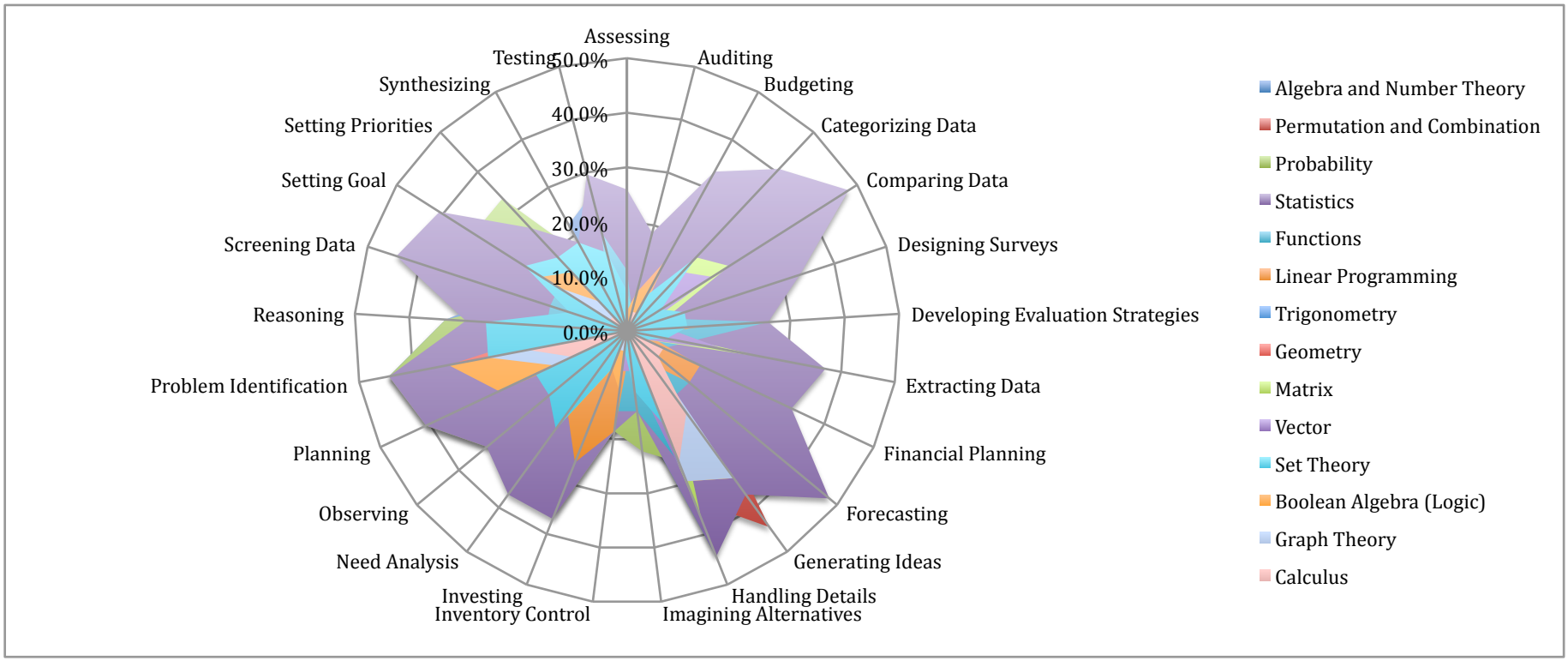


Figure 68: Radar Chart Showing Associations Between Skills and Concepts

The 'Heat map' matrix below presents another representation of the associations between skills and concepts. Whilst the red-tone cells show the greater contribution of concepts to corresponding skills, the blue tone cells present the weaker linkages of the concepts to those respective skills. For example, trigonometry does not contribute to the selected set of skills when comparing to algebra and number theory based on the judgment of the participating respondents. Interestingly, statistics and probabilities are salient concepts contributing to a wide range of skills.

	Algebra and Number Theory	Permutation and Combination	Probability	Statistics	Functions	Linear Programming	Trigonometry	Geometry	Matrix	Vector	Set Theory	Boolean Algebra (Logic)	Graph Theory	Calculus
Assessing	15%	4%	22%	26%	11%	4%	0%	4%	7%	7%	7%	4%	7%	0%
Auditing	7%	4%	11%	19%	4%	7%	0%	0%	4%	4%	4%	7%	0%	4%
Budgeting	30%	11%	22%	33%	11%	15%	0%	0%	4%	4%	7%	11%	0%	4%
Categorizing Data	33%	30%	22%	41%	4%	4%	4%	7%	19%	15%	19%	0%	0%	0%
Comparing Data	44%	19%	33%	48%	11%	4%	15%	15%	22%	19%	7%	0%	0%	0%
Designing Surveys	11%	26%	26%	33%	7%	0%	7%	4%	7%	4%	11%	0%	0%	0%
Developing Evaluation	26%	22%	26%	26%	26%	15%	4%	4%	4%	7%	11%	0%	0%	0%
Extracting Data	26%	7%	22%	37%	11%	4%	7%	11%	26%	19%	7%	0%	0%	0%
Financial Planning	26%	7%	30%	33%	7%	15%	0%	0%	4%	4%	4%	7%	0%	7%
Forecasting	19%	19%	44%	48%	15%	15%	4%	0%	7%	0%	0%	0%	4%	7%
Generating Ideas	26%	44%	37%	37%	15%	7%	22%	30%	15%	19%	26%	33%	33%	19%
Handling Details	44%	33%	26%	44%	26%	22%	30%	22%	37%	30%	19%	30%	30%	26%
Imagining Alternatives	15%	15%	22%	15%	15%	4%	7%	4%	4%	7%	11%	0%	0%	0%
Inventory Control	11%	15%	19%	19%	15%	19%	0%	0%	7%	7%	4%	11%	4%	0%
Investing	15%	15%	37%	37%	15%	26%	0%	0%	7%	4%	7%	7%	4%	7%
Need Analysis	22%	15%	19%	37%	19%	19%	11%	11%	22%	15%	22%	0%	0%	0%
Observing	19%	15%	33%	33%	15%	4%	7%	7%	7%	11%	19%	0%	0%	0%
Planning	26%	30%	41%	41%	11%	26%	15%	11%	15%	7%	19%	26%	15%	11%
Problem Identification	44%	33%	44%	44%	30%	15%	26%	33%	19%	22%	26%	33%	26%	19%
Reasoning	33%	30%	33%	30%	15%	26%	11%	11%	11%	15%	26%	0%	0%	0%
Screening Data	22%	11%	19%	44%	15%	4%	4%	0%	11%	7%	11%	0%	0%	0%
Setting Goal	19%	11%	33%	41%	15%	11%	4%	4%	7%	7%	22%	19%	15%	4%
Setting Priorities	0%	22%	33%	26%	11%	7%	0%	4%	4%	4%	19%	15%	7%	4%
Synthesizing	22%	19%	15%	19%	7%	4%	7%	4%	4%	4%	19%	0%	0%	0%
Testing	26%	15%	26%	30%	19%	7%	7%	0%	4%	15%	15%	0%	0%	0%

Figure 69: Heat Map Matrix Showing Associations Between Skills and Concepts

8.2. Questionnaire for Validating Defined Hypothesis

To investigate whether student motivation in learning is enhanced when the student can recognize subtle connections among concepts, skills and professions, another two sets of questionnaires was constructed to measure changes in students' intrinsic motivation level. The first set of the questionnaires is given to students to fill in before the students interact with the prototype and the second set is given to students after they have completed their interaction. Although all questions in these two questionnaires are alike in meaning, the wording of each question is not exactly the same. The readers can note the differences when comparing the two questionnaires included in appendix B.

Questions in these two questionnaires were designed based on two similar research papers on intrinsic motivation measurement and a report of a case study on motivation measurement. Like the first two sets of online questionnaires for creating the dynamic associations, participating students were expected to rate the their personal agreement with the given question statements on a four-point Likert scale.

8.2.1. Design of Questionnaire items

The questionnaire includes 6 demographic questions like age, gender, grade, etc. and about 66 questions designed to measure student's intrinsic motivation. Based on a case study[91] conducted by University of Berkeley Bear Center[92], three different variables were used in measuring motivation for college effectively:

- Behaviors towards school,
- Actions towards college, and

[91] Final report of case 2 is used for the development of motivation measures. Retrieved May 19, 2011 from http://bearcenter.berkeley.edu/GradeMap/download.php
[92] Retrieve May 19, 2011 from http://bearcenter.berkeley.edu/index.php

- Attitudes towards college

While the first two variables can suggest the positive behaviors of a student, which reflects the current level of the student's intrinsic motivation, the last variable "attitude toward college" measures the current beliefs and ideas of a post-secondary education. In the same vein, three variables in the Berkeley case study were used as a basis for designing the questionnaire items for validating defined hypothesis in this thesis. The questionnaire template is included in appendix C1. Because behaviors and actions toward schools and college shared some similarities, these two variables are combined as "student's current learning behaviors". For that reasons, the following three variables are used as motivation measures:

- Student's current learning behaviors
- Student's expected behaviors in the future (attitude toward behavioral changes) before using the prototype, and
- Student's expected future behaviors (attitude toward behavioral change) after using the prototype

To ensure whether the items are suitable for measuring motivation, a questionnaire template proposed by a research paper[93] on a new measurement scale of motivation is reviewed and adopt as a supplementary guideline of questionnaire item design. The new measurement scale of motivation was conceptualized and created using ordered subgroups of three main aspects of Motivation (i.e., Striving for excellence, Desire to Learn and Personal Incentives). The questionnaire template proposed by the research paper is included in appendix C2. In addition, the future

[93] Waugh, R. (2002). Creating a scale to measure motivation to achieve academically: Linking attitudes and behaviors using Rasch measurement. British Journal of Educational Psychology 72, 65-86.

orientation scale used in a Thai research paper regarding motivation measurement was studied to identify similar questionnaire items as well as suggesting the appropriate sentences for each questionnaire item. The questionnaire template used by the Thai research paper is included in appendix C3. The table below summarized all the key questions in the questionnaire.

		Questionnaire Template		
ID	**Question Statement**	**Berkeley Case Study No.2**	**Paper on New Scale to Measure Motivation**	**Future Orientation Scale (Thai)**
1	I focus on the lessons in classes	2	15/16	
2	I finish my homework	3	1/2	1
3	I raise up my hand to answer questions in the classroom	5		
4	I try different learning strategies when I have learning difficulties		5/6	
5	I consult friends when I have learning difficulties		31/32	
6	I consult teachers when I have learning difficulties	12	35/36	26
7	I recheck my homework to ensure accuracy	15	19/20	
8	I tend to study harder when I get a bad test score		11/12	9
9	I prepare for exams	6	3/4	2
10	I review the learning materials outside the classroom		33/34	
11	I set time for reviewing learning materials		37/38	33
12	I surf the Internet to expand my academic knowledge base		33/34	
13	I read supplementary books to enrich my understanding of class materials		33/34	
14	I seek for activities inside and outside schools to help me learn		9/10	
15	I plan my study myself		39/40	18
16	I like to do assignments in group	11	41/42	

17	I like the social relationships in academic work		47/48	
18	I have interest in a number of academic topics		23/24	
19	I think about my values when I have conflicts about time to be spent on achieving		21/22	5
20	I enjoy intellectual challenges		45/46	
21	I am interested in solving a problem set with which others have difficulties		27/28	
22	I set myself realistic but challenging goals		7/8	

Table 34: Summary of Questions Measuring Intrinsic Motivation

Because current-learning behaviors, expected behaviors before using the prototype, and expected future behaviors after using the prototype are the three variables used as motivation measures, all the questions listed in the table 34 were rephrased to provide a sense of all three variables. For example, "I focus on the lesson in class" is a question item for online questionnaire identifying current-learning behaviors but the same question item will be rephrased to "I **will** focus on the lesson in class" for the questionnaire identifying expected behaviors **before** using the prototype and to "**From now on**, I will focus on the lesson in class" for the questionnaire identifying expected behaviors **after** using the prototype.

8.2.2. Outcome Space

The outcome spaces can be categorized into four answer choices where the summary of outcome space is in the table below:

Answer Choice	Score
Strongly Disagree	**0**
Somewhat Agree	**1**
Agree	**2**
Strongly Agree	**3**

Table 35: Possible Outcome Space

8.2.3. Data Analysis of Questionnaires

8.2.3.1. Descriptive Statistics of Questionnaire Respondents

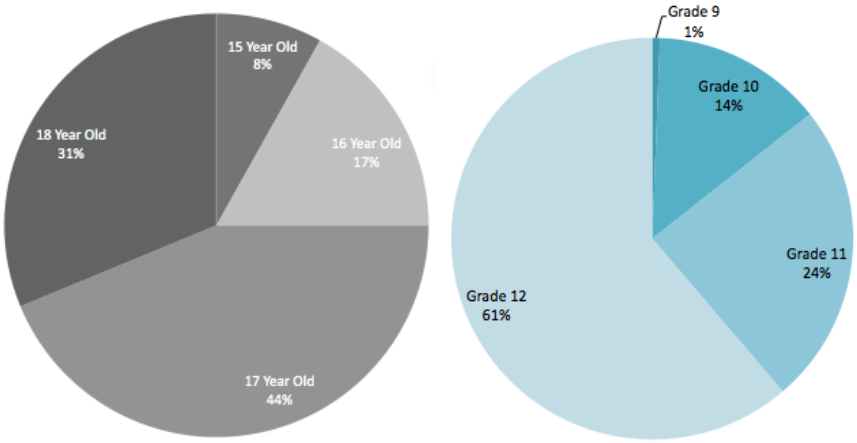


Figure 70: Descriptive Statistics of Questionaire Respondents (Age and Grade)

The last two sets of online questionnaires were randomly distributed to students in several high schools—the there were 160 students participating in the survey. Most respondent students were in grade 12 (62% of total participating students), which is the last grade of the high schools before transitioning to the university level.

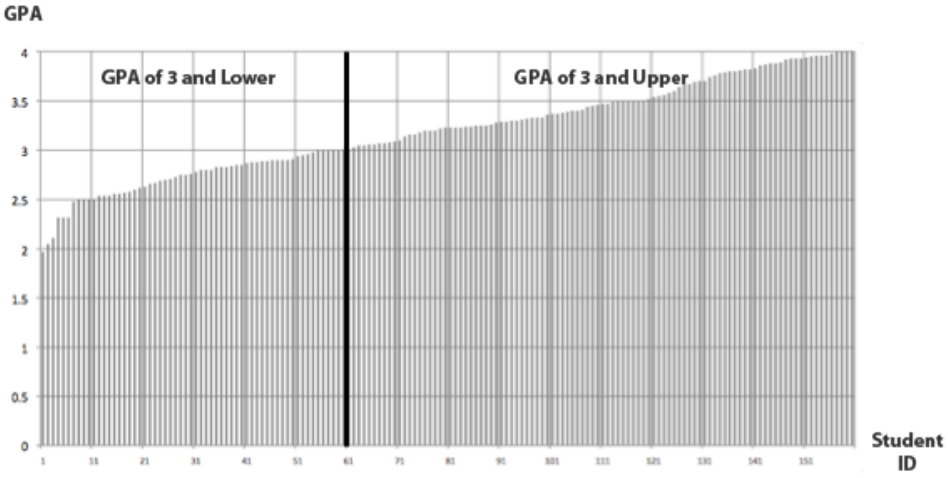


Figure 71: Descriptive Statistics of Questionaire Respondents (Student GPA)

As shown in the figure 71, the x-axis represents the participating students while the y-axis represents the GPA of each corresponding student. Interestingly, more than half of the participating students received a GPA of 3 and upper. Specifically, about 60

participating students got GPA of 3 and lower while the rest (about 100) got GPA higher than 3.

Both descriptive statistics (e.g., grade and GPA) suggest that a group of students who are graduating from high schools or have a high GPA are more eager to try the prototype than other groups of students. One reason might be that they think the prototype will assist them to make an informed decision about what majors they want to pursue further. Also, it makes sense that grade-12 students with high GPA would choose their their next move more carefully than any other student groups.

8.2.3.2. Questionnaire Result Before Students Use Prototype

Before using the prototype, participating students were invited to fill in the first self-report online questionnaire. The objective of the first questionnaire is to quantitatively measure the differences between current behaviors and expected behaviors before the students play with the prototype. There were 160 students responding to this first round, resulting in the questionnaire result summarized in figure 72. The x-axis indicates the difference between current behaviors and expected behaviors in term of percentage. For example, the result of a questionnaire item of "I set myself realistic but challenging goals" is equal to +45.96%, which means participating students expect to set realistic but challenging goals 46% more than they currently do. Although students' attitude towards behavioral changes appears positive in almost aspects, there are two negative items, which are an item of "I like the social relationship in academic work" (-3.11%) and "I like doing assignment in group" (-7.45%).

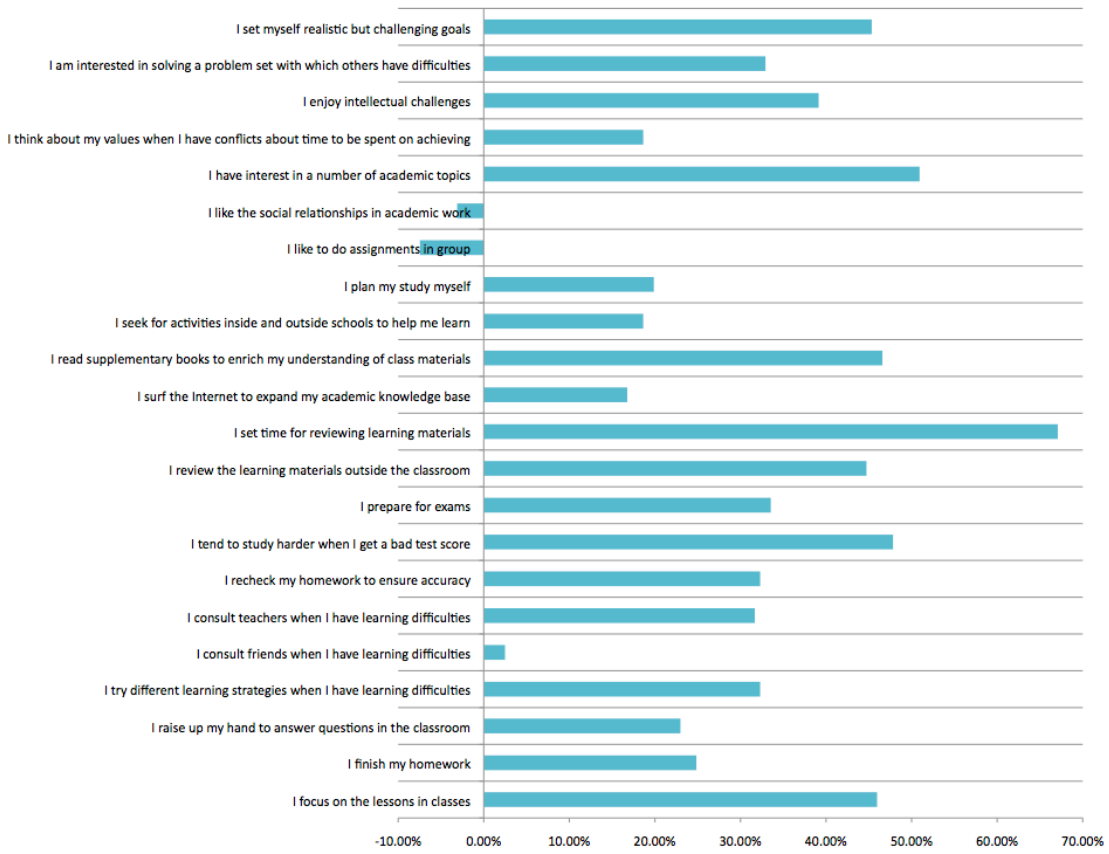


Figure 72: Differences Between Student's Actual Behaviors and Student's Attitude Toward Behavioral Changes Before Using Prototype

To investigate the reason of these two negative numbers, a couple of phone interviews with randomly chosen students were conducted further. It turned out that many active students deemed that working on an individual assignment was more effective than group work. In one case, an active learner found it challenging to work in a team whose members are passive learners. This result corresponds to the fact that most participating students were relatively active students (60% of participating students received a GPA of 3 or higher as shown in figure 71), who tend to prefer working alone over working in a team with passive learners.

8.2.3.1. Questionnaire Result After Students Use Prototype

Participating students in the first questionnaire were then invited to fill in the second self-report online questionnaire after using the prototype the prototype. The purpose of this follow-up questionnaire was to quantitatively measure:

- The differences between current behaviors and expected behaviors **after students interact with the prototype**, and
- The difference between expected behaviors before using the prototype and after using the prototype.

There were only 16 participating students who replied to both the first (before using the prototype) and second self-report online questionnaire (after using the prototype), which accounts for 10% of total participating students who replied to the first online questionnaire. The questionnaire result can be summarized in figure 73. Similar to prior questionnaire, the x-axis indicates the difference between current behaviors and expected behaviors in term of percentage. In figure 73, the result shows a combination of positive and negative students' attitude towards behavioral changes. Although 19 questionnaire items indicate the positive change in intrinsic motivation after using the prototype, there were still three negative items after using the prototype:

- I think about my values when I have conflicts about time to spent on achieving (-1.96%)
- I consult friends when I have learning difficulties (-5.88%), and
- I finish my homework (-1.96%)

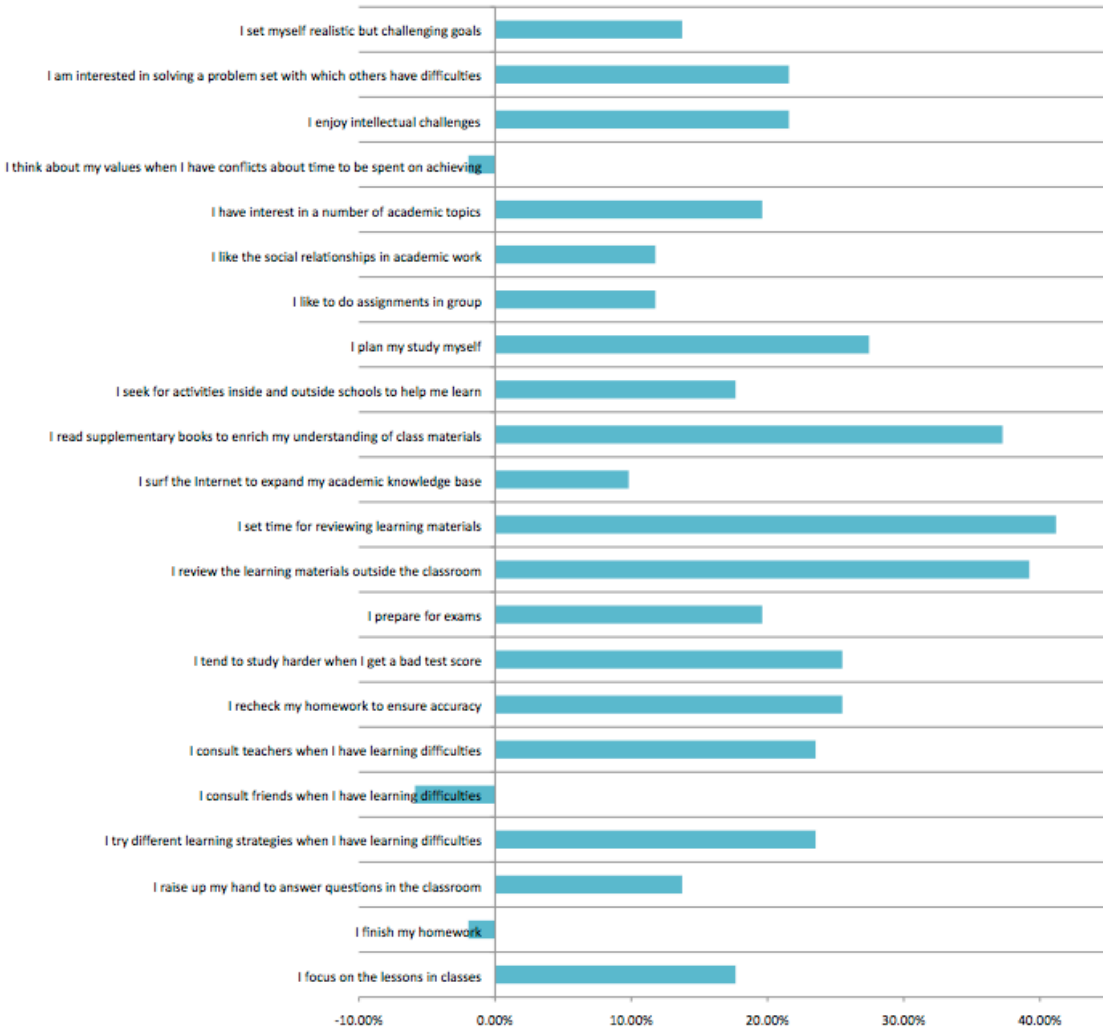


Figure 73: Differences Between Student's Actual Behaviors and Student's Attitude Toward Behavioral Changes After Using Prototype

The result of the first questionnaire is compared to that of the second questionnaire to identify the differences of students' attitude toward behavioral changes before and after using the prototype. Based on the input of 16 participating students, the comparison is presented in the figure 74 where there were four negative items:

- "I finish my homework" (-9.80%)
- I think about my values when I have conflicts about time to spent on achieving (-7.84%)
- I have interest in a number of academic topics (-5.88%), and

- I seek for the activities to help me learn (-1.96%)

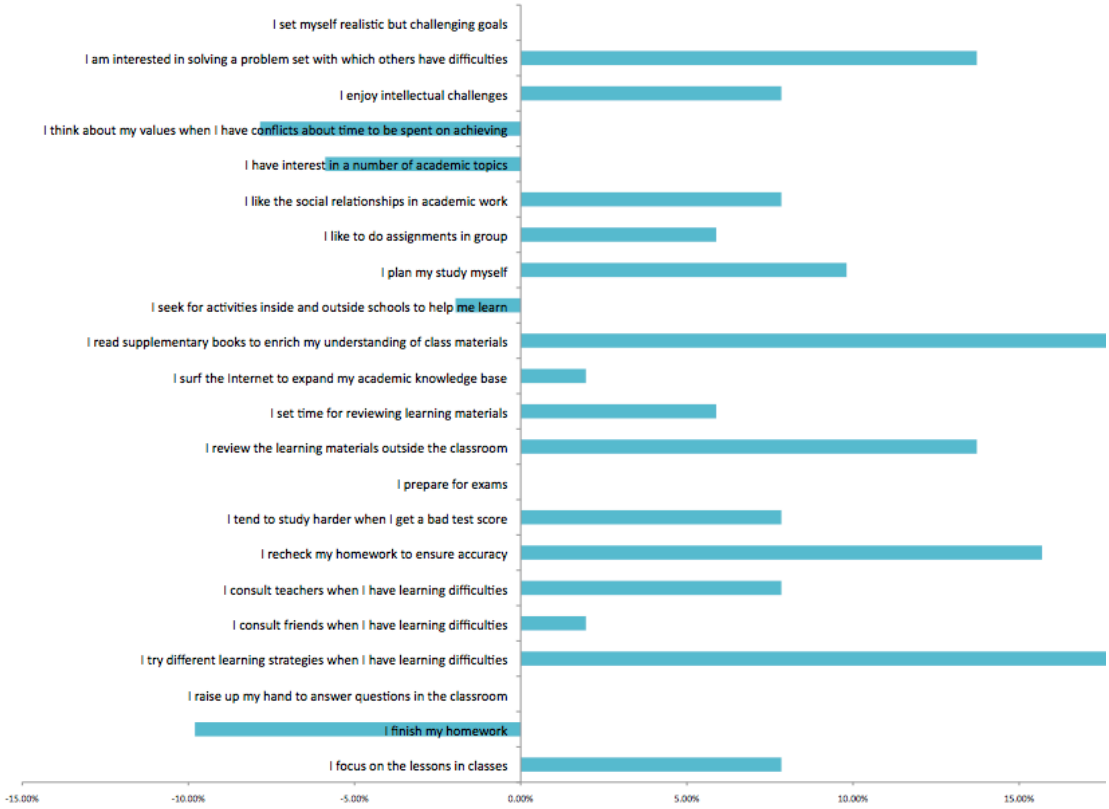


Figure 74: Differences Between Student's Attitude Toward Behavioral Changes Before Using Prototype and After Using Prototype

Due to the small number of respondents in the second online questionnaire, a couple of phone interviews with randomly chosen students were conducted to gain additional insights about the prototype. It appears that the prototype can help cultivate a "**systematic thinking**" in students. One student admitted that he always thinks about what kind of professions he would like to be involved in but he looked over the development of necessary skills as a middle step before reaching his dream professions. He also mentioned that the prototype helps him to know what concepts might be useful for his desired professions.

Interestingly, while high-GPA students could understand and derive meaning from the complex PSC (Profession-Skill-Concept) network, several medium-GPA

students could not. The complex association between professional goals and concepts is one important barrier for students to recognize the associations, resulting in students' disinterest in continually interacting with the prototype and replying the to the second questionnaire. Also, most students reported that the prototype has a limited number of professions and concepts. The application would serve them better if more professions and concepts were available for selection. Also, when some students were interested in developing a particular skill, the students need to click on the "learning plan" button to identify recommended learning activities, which is not obviously presented in the first place. Hence, the students didn't have a clear picture what the "next step" in this application should be.

9. Conclusion

To cultivate an active and self-directed learning mindset in learners, learning systems need to encourage the student to take more ownership of his or her learning choices. Because the overall quality of learning systems cannot be significantly improved without qualified mentors, despite advances in technologies and richness of learning environments, the learner must be empowered when the mentor is under-qualified. Based on a wide range of literature and reports, this study carefully synthesizes system design principles that empower the learner to tackle temporary shortage of qualified mentor entity in learning systems at a certain time span. The result of the system design principles is system architecture of intrinsically motivated learning systems, which promote the transformation process of the learners' mindset from a passive mode to a more active and self-directed mode.

A dynamic interaction between a learner and learning environments is the key to intrinsically motivated learning systems. Immediate feedback from learning environments can speed up the process of self-exploration, resulting in self-understanding and stimulating the learner's intrinsic needs of self-actualization, which is at the top of Maslow's hierarchy of needs. For example, a learner begins their learning journey by exploring surroundings until he or she finds a focusing set[94] of "objects-to-think-with", leading to the initial set of self-defined learning objectives. With feedback from learning environments (e.g., advice from mentors, conversations with peers, self-constructed understandings, etc.), the learner gains more understanding about the

[94] It is important to note that the interesting set of "objects-to-think-with" can change over time (i.e., increase and decrease), resulting in the change in self-defined learning objectives.

focusing set[95] of "objects-to-think-with", resulting in a greater clarity of self-defined learning objectives. This learning cycle helps the learner to understand the consequences of his own actions, resulting in deeper self-understanding. To achieve the desired results, he would adjust his own actions until he reaches a state of self-actualization.

The perceived ability to both understand the focusing set of "objects-to-think-with" and accomplish the self-defined learning objectives comes into play in maintaining the learning effort. If the learner believes in his ability to accomplish the self-defined learning objectives, he would consistently put learning effort to a series of learning activities until he accomplishes the learning objectives. If the learner is not confident in his ability, personalized "bite-sized" learning activities must be provided to encourage him to consistently expend effort until the learning objectives are accomplished.

As a result, the system architecture is designed to help learners define their personal learning objectives, which align with his or her intrinsic needs. Since some of the common human intrinsic needs are personal growth and development, the system architecture focuses on the development of skills needed for achieving desired professional goals. By recommending "bite-size" learning activities of relevant knowledge concepts based on self-selected skills, the learners are **theoretically** motivated to learn. Although the prototype developed based on the proposed system architecture cannot demonstrate a provable conclusion due to insufficient data points, it might be still difficult, even with many more data points, to measure the effect of prototype on learner's mindset. Seymour Papert once said in his renowned book:

[95] It is importantly note that the interesting set of "objects-to-think-with" can change over time (i.e., increase and decrease), resulting in the change in self-defined learning objectives.

"I remember that my first encounter with the differential gears was second year. If any scientific educational psychologist had tried to measure the effect of this encounter, he would probably have failed. It had profound consequences but, I conjecture, only very many years later. A pre- and post- test at age two would have missed them."

10. Limitations and Future Work

A limitation of the work in this thesis research is the quantity of active participating students and variety of heterogeneous student groups. Since the targeted groups of this study were high school students in Thailand, where most students don't have immediate access to the Internet at home, students were not excited enough to spend extra money and time at Internet cafes to interact with the prototype, resulting in the limited number of participating students. To cope with this limitation, one possible future activity is to coordinate with school counselors to setup a session in which students can interact with the prototype at school.

Based on the online questionnaire, participating students also suggest that the prototype should include more professions and concepts, which will allow the prototype to satisfy a wider variety of students' needs. For that reason, possible future work would be to extend the number of available professions and concepts in high school. In addition, the associations constructed in the prototype should be periodically validated by a larger number of experienced professionals to ensure the most up-to-date information. Last but not least, a self-assessment module could be integrated into the prototype to immediately reflect student's learning effort. Thus, students could quickly adjust their learning strategies to successfully achieve their defined learning goals.

11. References

Chapter 1

Obama, B. (2009, September), *Obama's Speech on Importance of Education*. Retrieved May 10, 2011 from http://www.upi.com/Top_News/2009/09/08/Obamas-speech-on-importance-of-education/UPI-21501252429738/#ixzz1Lyn6NYyh

UNESCO. (1999). *The Declaration on Science and the Use of Scientific Knowledge*. Retrieved April 9, 2010 from http://www.unesco.org/bpi/science/content/docum/declare.htm

AACU. (2005). *Liberal Education outcomes – A Preliminary Report on Student Achievement in College*. Retrieved May 12, 2010 from http://www.aacu.org/advocacy/pdfs/leap_report_final.pdf

UNESCO. (2007). *Global Education Digest 2007*. Retrieved on May 11, 2011 from http://www.uis.unesco.org/template/pdf/ged/2007/EN_web2.pdf

Memon, G.R. (2007, Spring). Education in Pakistan: The Key Issues, Problems and The New Challenges. *Journal of Management and Social Sciences 3*(1), 47-55. Retrieved May 12, 2011 from http://www.biztek.edu.pk/downloads/research/jmss_v3_n1/5%20EDUCATION%20IN%20PAKISTAN.pdf

Akiba, M., LeTendre, G. & Scribner, J. (2007, July). Teacher Quality, Opportunity Gap, and National Achievement in 46 Countries. *Educational Researcher 36*(7). 369-387. Retrieved May 12, 2011 from SAGE Journal Online

Sturtevant D. (2008, September). *America Disrupted: Dynamics of the Technical Capability Crisis*. Retrieved May 12, 2011 from https://lgosdm.mit.edu/VCSS/servlet/LoadFile?VIEW=4&file=/Thesis/25371/Sturtevant%20thesis.pdf

Pink, D. (2009). Drive: The Surprising Truth About What Motivates Us, Retrieved May 11, 2011 from http://www.danpink.com/drive

Braunger, J., & Lewis, J. (1998). Building a knowledge base in reading, 2nd edition. Newark, NJ. International Reading Association.

Chapter 2

OECD. (2006). Top of the class – High Performers in Science in PISA 2006. Paris, France. OECD Publication

Kraus, M.W., Keltner, D. (2008). Signs of Socioeconomic Status: A Thin-Slicing Approach. *Psychological Science* 20 (1), 99–106. Retrieve May 10, 2011 from http://pss.sagepub.com/content/20/1/99

Fry, G. (2002). *The Evolution of Educational Reform in Thailand.* Retrieve May 18, 2011 from http://www.worldedreform.com/intercon2/fly.pdf

Ylä-Anttila, P. & Palmberg, C. (2007). *Economic and Industrial Policy Transformations in Finland.* Journal of Industry, Competition and Trade 7(3), 169-187. Retrieve May 18, 2011 from http://www.springerlink.com/content/c054l28511075711/fulltext.pdf

Dahlman, C., Routti, J. & Yla-Anttila, P. (2007, December). *Finland as a Knowledge Economy: Elements of Success and Lessons Learned*. World Bank Publications. Washington, DC.

Chapter 3

Ministry of Education. (2008). *Towards A Learning Society in Thailand*. Retrieved on May 13, 2011 from http://www.bic.moe.go.th/fileadmin/BIC_Document/book/intro-ed08.pdf

BUREAU OF THE BUDGET. (2011). *THAILAND'S BUDGET IN BRIEF FISCAL YEAR 2011*. Retrieved on May 13, 2011 from http://www.bb.go.th/FILEROOM/CABBBIWEBFORM/DRAWER14/GENERAL/DATA0001/00001246.PDF

Kohtbantau, A. & Fitts, P. (2006, October). *Thailand's Secondary Education System at a Crossroads: Despite Impressive Increases in Access to School, Challenges Remain.* Retrieved on May 13,2001 from http://www.worldbank.or.th/WBSITE/EXTERNAL/COUNTRIES/EASTASIAPACIFICEXT/THAILANDEXTN/0,,contentMDK:21085719~menuPK:333302~pagePK:2865066~piPK:2865079~theSitePK:333296,00.html

Hallinger, P. Kantamara, P. (2009). Paper prepared for the *Asia Pacific Journal of Education.* Retrieved on May 13, 2011 from http://www.philiphallinger.com/papers/APJE.pdf

Prapphal, K. (2003). English proficiency of Thai Learners and Directions of English Teaching and Learning in Thailand. *Journal of English Studies 1*(1). 6-12.

Cavallo, D. (1998). Project Lighthouse in Thailand: Guiding Pathways to Powerful Learning. Retrieved on May 13, 2011 from http://el.media.mit.edu/logo-foundation/pubs/logoupdate/v7n1/v7n1-lighthouse.html

Inprasitha, M.. (2006). Tsukuba Journal of Educational Study in Mathematics (25). Retrieve on May 13, 2011 from http://www.human.tsukuba.ac.jp/~mathedu/journal/vol25/inprasitha.pdf

Chapter 4

Smith, M. K. (1999). *'Learning theory', the encyclopedia of informal education*. Retrieve May 20, 2011 from www.infed.org/biblio/b-learn.htm

Aspin, D. & Chapman, J. (2007). Philosophical Perspectives on Lifelong Learning. Lifelong Learning Book Series 11, 19-38. Springer Netherlands. Retrieved on May 15, 2011 from http://www.springerlink.com/content/v32786303p48262w/

Fischer, G. (1999). Lifelong Learning: Changing Mindsets. Retrieved May 15, 2011 from http://www.cs.colorado.edu/~gerhard/papers/icce99.pdf

Agran, M. & Wehmeyer, M. (2000). *Promoting Transition Goals and Self-Determination Through Student Self-Directed Learning: The Self-Determined Learning Model of Instruction*. Education and Training in Mental Retardation and Developmental Disabilities *35*(4), 351-364. Retrieve May 15, 2011 from http://www.beachcenter.org/research/FullArticles/PDF/SD9_Promoting%20Transition%20Goals%20and%20Self-Determination.pdf

Siegel, I., Brodzinsky, D. & Golinkoff, R. (1981). *New directions in Piagetian theory and practices*. Hillsdale, NJ. Lewrence Erlbaum Assiciates, Inc.

Papert, S. (1980). *Mind-storms Children, Computers, and Powerful Ideas*. Basic Books, Inc.

Bodrova, E. & Leong D. (2007). *Tool of the mind: the Vygotskian approach to early childhood education*. Upper Saddle River, NJ. Pearson Education, Inc.

Chapter 5

Sansone, C. & Harackiewicz, J. (2000). Intrinsic and Extrinsic Motivation: The Search for Optimal Motivation and Performance. Orlando, FL: Academic Press.

Ryan, R. (2009, June). *Self-determination Theory and Wellbeing*. Retrieved May 15, 2011 from http://www.welldev.org.uk/wed-new/network/research-review/Review_1_Ryan.pdf

Chapter 6

IEEE Computer Society sponsored by Learning Technology Standards Committee. (2003). *IEEE Standard for Learning Technology-Learning Technology Systems Architecture (LTSA).* Retrieved May 15, 2011 from http://ieeexplore.ieee.org/xpls/abs_all.jsp?isnumber=28129&arnumber=1257919&tag=1

Metlife. (2006). *2006 MetLife Survey of the American Teacher: Expectations and Experiences*. Retrieve May 15, 2011 from http://www.eric.ed.gov/PDFS/ED496558.pdf

National Comprehensive Center for Teacher Quality and Public Agenda. (2007). *Lessons Learned: New Teachers Talk About Their Jobs, Challenges and Long-Range Plans*.

Retrieved May 15, 2011 from
http://www.tqsource.org/publications/LessonsLearned1.pdf

University of Michigan (2007, December). Parents Want Teachers Who Make Children Happy. *ScienceDaily*. Retrieved May 16, 2011, from
http://www.sciencedaily.com/releases/2007/12/071206163305.

Philly.com. (2010, July). *What do parents want from school?* Retrieved May 15, 2011 from http://articles.philly.com/2010-07-15/news/24968079_1_charter-schools-parental-choice-school-parents

Ad Hoc Parent Engagement Policy Development Committee of the Parent Collaborative. (2006, December). Los Angeles Unified School District Parent Needs Assessment Survey Results. Retrieved May 15, 2011 from
http://latimesblogs.latimes.com/parent_needs_assessment_report-FINAL.pdf

Wagner, N., Hassanein, K., & Head, M. (2008). Who is responsible for E-Learning Success in Higher Education? A Stakeholders' Analysis. *Educational Technology & Society*, *11* (3), 26-36. Retrieved May 15, 2011 from http://www.ifets.info/journals/11_3/3.pdf

Higher Education Strategy Associates. (2010, February). Tuition Fees and Student Financial Assistance 2010 Global Year in Review. Retrieved May 15, 2011 from
http://www.higheredstrategy.com/publications/2011/Year_in_Review_2010.pdf

K. Anders Ericsson. (2009). Development of professional expertise: toward measurement of expert performance and design of optimal learning environments. New York, NY. Cambridge University Press

Amer, A. (2006). Reflections on Bloom's Revised Taxonomy. *Electronic Journal of Research in Educational Psychology 4*(1). 213-230. Retrieved May 15, 2011 from
http://www.investigacion-psicopedagogica.org/revista/articulos/8/english/Art_8_94.pdf

Gruber, T. & Olsen, G. (1994). *An Ontology for Engineering Mathematics.* Retrieve May 15, 2011 from http://www-ksl.stanford.edu/knowledge-sharing/papers/engmath.html

Cook, D. *Ontology of Physics for Biology.* Retrieve May 15, 2011 from
http://www.bhi.washington.edu/research/SemBioProcess/OPB.htm

Chapter 7

Spring, T. (1999). Inxight Shakes the Tree of Knowledge. *PCWorld.* Retrieve May 16, 2011 from
http://www.pcworld.com/article/10473/inxight_shakes_the_tree_of_knowledge.html

Karren, A. (2006). *Interactive Visualization of Graph Pyramids*. Retrieved May 16, 2011 from http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.60.7885

Robertson, G., Mackinlay, J. & Card, S. (1991). *Cone Trees: Animated 3D Visualizations of Hierarchical Information*. Retrieve May 16, 2011 from

http://www2.parc.com/istl/groups/uir/publications/items/UIR-1991-06-Robertson-CHI91-Cone.pdf

Fierlinger, P. (2009). *Fake It Till You Make It: Rapid Prototyping Using Flash*. Retrieved May 16, 2011 from http://www.web2expo.com/webexsf2009/public/schedule/detail/8860

Chapter 8

Waugh, R. (2002). Creating a scale to measure motivation to achieve academically: Linking attitudes and behaviors using Rasch measurement. British Journal of Educational Psychology 72, 65-86.

Appendix A1: Online Questionnaire Questions for Creating Dynamic Associations between professions and skills

Section 1: About yourself

1.) Your age? / อายุของคุณ?

2.) Your nationality? / สัญชาติของคุณ?

3.) What is your highest degree? / คุณสำเร็จการศึกษาขั้นสูงสุดระดับใด?

( ) Doctoral Degree / ปริญญาเอก

( ) Master Degree / ปริญญาโท

( ) Bachelor Degree / ปริญญาตรี

( ) High School / มัธยมศึกษาตอนปลาย

( ) Middle School / มัธยมศึกษาตอนต้น

( ) Primary School / ประถมศึกษา

4.) What are your five most important values? / กรุณาเลือก 5 ค่านิยมที่สำคัญที่สุดกับตัวคุณ?

[ ] Achievement (Sense of accomplishment) / ความสำเร็จ

[ ] Advancement (Moving forward in your career through promotion) / ความก้าวหน้า

[ ] Adventure (Involving with risk taking) / การผจญภัยและความเสี่ยงทั้งด้านดีและไม่ดี

[ ] Aesthetics (Appreciating the beauty of ideas, things, etc.,) / ความสวยงามทางศิลปะ

[ ] Autonomy (Working independently) / ความสามารถในการพึ่งพาตนเอง

[ ] Caring (Love, Affection) / ความรักและความห่วงใย

[ ] Challenge (Stimulating full use of your potential) / ความท้าทายเพื่อไว้ทดสอบความสามารถของตนเอง

[ ] Change and Variety (Frequent work responsibilities) / ความหลากหลาย

[ ] Competition (Pitting your abilities against others where there is clear win and lose outcomes) / การได้ชัยชนะเหนือคู่แข่ง

[ ] Cooperation (Working as a team) / ความร่วมมือ

[ ] Creativity (Being imaginative) / ความคิดสร้างสรรค์แปลกใหม่

[ ] Economic Security (Having enough money) / ความมั่นคงทางการเงิน

[ ] Excitement (Experiencing frequent excitement in your work) / ความตื่นเต้นกับงานที่แปลกใหม่

[ ] Family Happiness (Being able to spend time with family) / ความสุขของครอบครัว

[ ] Friendship (Developing a close personal relationship) / มิตรภาพที่ดีกับคนรอบข้าง

[ ] Health (Physical well being) / สุขภาพที่แข็งแรง

[ ] Help Others (Involving with in helping people) / การได้ช่วยเหลือคนอื่น

[ ] Help Society (Doing something to contribute to the betterment of the world) / การได้ช่วยเหลือสังคม

[ ] Inner Harmony (Being a peace with oneself) / ความสงบสุขในจิตใจตนเอง

[ ] Integrity (Sincerity and honesty) / ความถูกต้องและความจริงใจ

[ ] Intellectual Status (Being regarded as as an expert in the field) / การได้รับการยกย่องในความสามารถ

[ ] Knowledge (Understanding gained through study and experience) / การได้เรียนรู้สิ่งใหม่ ๆ

[ ] Leadership (Influence over others) / ความเป็นผู้นำ

[ ] Leisure (Having time for hobbies, sports, activities and interests) / การมีเวลาเพื่อกิจกรรมที่สนใจ

[ ] Loyalty (Steadfastness and allegiance) / ความซื่อสัตย์และความจงรักภักดี

[ ] Pleasure (Enjoyment) / ความสนุกสนาน

[ ] Power (Authority) / อำนาจ

[ ] Precision (Working with situations where there is little tolerance for error) / ความแม่นยำ

[ ] Responsibility (Being Accountable for the result) / ความรับผิดชอบ

[ ] Recognition (Getting acknowledge for your contribution) / การได้รับความยอมรับจากคนรอบข้าง

[ ] Stability (Not like to change over a long time period of time) / ความสม่ำเสมอในชีวิต

[ ] Spirituality / ความดีงาม ความสุขทางจิตวิญญาณ

[ ] Time Freedom (Working on your own schedule) / ความยืดหยุ่นในเวลาการทำงาน

[ ] Wealth (Profit, Making a lot of money) / ความร่ำรวยมั่งคั่ง

[ ] Wisdom (Understanding based on accumulation of knowledge) / การมีปัญญาที่แท้จริง

Section 2: About your organization

5.) What industry is your organization? / องค์กรของคุณอยู่ในวงการใด?

( ) Accounting / บัญชี

( ) Advertising / โฆษณา

( ) Aerospace and Aviation / อากาศยานและการบิน

( ) Automotive / ยานยนต์

( ) Agriculture/Forestry/Fishing / เกษตรกรรม ป่าไม้ ประมง

( ) Biotechnology / เทคโนโลยีชีวภาพ

( ) Hotels and Lodging Places / บริการที่พัก

( ) Computers (Hardware, Desktop Software) / คอมพิวเตอร์

( ) Communications / สื่อสาร

( ) Construction/Home Improvement / ก่อสร้าง พัฒนาที่อยู่อาศัย

( ) Consulting / ให้คำปรึกษา

( ) Education / การศึกษา

( ) Engineering/Architecture / วิศวกรรม สถาปัตยกรรม

( ) Entertainment/Recreation / บันเทิง

( ) Finance/Banking/Insurance / การเงิน ธนาคาร ประกัน

( ) Food Service / อาหาร

( ) Government/Military / ราชการ ทหาร

( ) Healthcare/Medical / บริการสุขภาพ รักษาพยาบาล

( ) Internet / อินเตอร์เนท

( ) Legal / กฎหมาย

( ) Manufacturing / ผลิต

( ) Marketing/Market Research/Public Relations / การตลาด วิจัยตลาด ประชาสัมพันธ์

( ) Media/Printing/Publishing / สื่อการพิมพ์

( ) Mining / เหมืองแร่

( ) Non-Profit / องค์กรไม่แสวงหาผลกำไร

( ) Pharmaceutical/Chemical / เภสัชกรรม เคมีภัณฑ์

( ) Research/Science / วิจัย วิทยาศาสตร์

( ) Real Estate / พัฒนาอสังหาริมทรัพย์

( ) Retail / จัดขายปลีก

( ) Telecommunications / การสื่อสารโทรคมนาคม

( ) Transportation and Distribution / ขนส่งและกระจายสินค้า

( ) Utilities / สาธารณูปโภค

( ) Wholesale / จัดขายส่ง

( ) Professional Services / บริการเฉพาะทาง

( ) Other / อื่นๆ

( ) Don't work / ไม่ทำงาน

6.) Your organization size worldwide (in person)? / องค์กรของคุณมีจำนวนคนทั้งหมดเท่าไร?

( ) 1

( ) 2-4

( ) 5-9

( ) 10-19

( ) 20-99

( ) 100-499

( ) 500-9,999

( ) 10,000+

( ) Don't work / ไม่ได้ทำงาน

Section 3: About your CURRENT (or recent) job

7.) Your specific job function? / ลักษณะงานของคุณ?

( ) Accounting / งานบัญชี

( ) Administration / งานควบคุมดูแล

( ) Advertisement/PR / งานโฆษณา

( ) Architecture / งานสถาปัตยกรรม

( ) Arts/Leisure / งานศิลปะ

( ) Banking / งานธนาคาร

( ) Beauty/Fashion / งานเสริมความงาม

( ) Buying/Purchasing / งานจัดซื้อ

( ) Clerical/Reception / งานเสมียน งานต้อนรับ

( ) Computer Hardware / งานด้านอุปกรณ์คอมพิวเตอร์

( ) Computer Software / งานด้านโปรแกรมคอมพิวเตอร์

( ) Construction / งานจัดการการก่อสร้าง

( ) Consulting / งานให้คำปรึกษา

( ) Customer Service / งานบริการลูกค้า

( ) Design / งานออกแบบ

( ) Distribution / งานกระจายสินค้า

( ) Education / งานด้านการศึกษา

( ) Entertainment / งานบันเทิง

( ) Finance / งานด้านการเงิน

( ) Health Care (Physical and Mental) / งานบริการสุขภาพ

( ) Human resources management / งานจัดการทรัพยากรบุคคล

( ) Logistics / งานวางแผนจัดส่งสินค้า

( ) Management (Senior/Corporate) / งานจัดการ

( ) News/Information / งานข่าว

( ) Operations / งานปฏิบัติการ

( ) Planning (Meeting, Events, etc.) / งานวางแผน

( ) Production / งานผลิต

( ) Real Estate / งานพัฒนาและจัดการอสังหาริมทรัพย์

( ) Research / งานวิจัย

( ) Restaurant/Food service / งานด้านอาหาร

( ) Sales/Marketing / งานขาย งานการตลาด

( ) Science/Technology / งานด้านวิทยาศาสตร์และเทคโนโลยี

( ) Social service / งานบริการสังคม

( ) Student / นักเรียน นักศึกษา

( ) Other / งานอื่นๆ

( ) N/A-Unemployed/Retired/Homemaker / ว่างงาน เกษียณ

8.) Your job level? / ระดับตำแหน่งของคุณ?

( ) Top Level Executive / ผู้บริหารขั้นสูง

( ) Senior Vice President / รองประธานอาวุโส

( ) Vice President / รองประธาน

( ) Director / ผู้จัดการฝ่าย

( ) Manager / ผู้จัดการแผนก

( ) Supervisor / หัวหน้าแผนก

( ) Team Lead / หัวหน้าทีมงาน

( ) Senior Professional / พนักงานอาวุโส

( ) Professional / พนักงาน

( ) Administrative/Support personnel / พนักงานฝ่ายสนับสนุน ดูแล

( ) N/A- Unemployed/Retired/Homemaker / ว่างงาน เกษียณ

9.) Your specific job title? / ตำแหน่งงานของคุณ?

10.) Job description? / กรุณาอธิบายสั้น ๆ เกี่ยวกับบทบาทงานของคุณ?

11.) Your monthly salary in US dollars (before tax)? / รายได้ต่อเดือนก่อนหักภาษี เป็นดอลล่าร์สหรัฐ?

( ) No Income / ไม่มีรายได้

( ) $250 or lower / รายได้ต่ำกว่า 8,750 บาท

( ) $251 - $500 / 8,751 - 17,500 บาท

( ) $501 - $750 / 17,501 - 26,250 บาท

( ) $751 - $1,000 / 26,251 - 35,000 บาท

( ) $1,001 - $1,500 / 35,001 - 52,500 บาท

( ) $1,501 - $2,000 / 52,501 - 70,000 บาท

( ) $2,001- $2,500 / 70,001 - 87,500 บาท

( ) $2,501- $3,500 / 87,501 - 122,500 บาท

( ) $3,501- $5,000 / 122,501 - 175,000 บาท

( ) $5,001- $6,500 / 175,001 - 227,500 บาท

( ) $6501 - $8,000 / 227,501 - 280,000 บาท

( ) $8,001 - $10,000 / 280,001 - 350,000 บาท

( ) $10,001 or higher / 350,001 บาทหรือมากกว่า

12.) How satisfied are you with your current (or recent) job? / บอกเล่าระดับความพอใจในตัวงานของคุณ?

( ) Very Satisfied / พอใจเป็นอย่างมาก

( ) Satisfied / พอใจ

( ) Neutral / เฉย ๆ

( ) Dissatisfied / ไม่ค่อยน่าพอใจ

( ) Very Dissatisfied / ไม่น่าพอใจเป็นอย่างมาก

Section 4: You critical skills needed for your job

13.) How necessary are these skill groups for your job? / ความสามารถเหล่านี้สำคัญมากน้อยเพียงใดต่องานของคุณ?

	Always Need / ขาดความสามารถนี้ไม่ได้	Substantially Need / เป็นความสามารถสำคัญต่องาน	Somewhat Need / ใช้ความสามารถนี้บ้าง	No Need / ไม่จำเป็นต้องใช้ความสามารถนี้
Analytical and Calculating Skills / ความสามารถในการวิเคราะห์และการคำนวณ	( )	( )	( )	( )
Management and Leadership Skills / ความสามารถในการจัดการ	( )	( )	( )	( )
Human Relation Skills / ความสามารถในการเข้ากับคนอื่นได้ดี เข้าถึงคน	( )	( )	( )	( )
Financial Skills / ความสามารถด้านบัญชีและการเงิน	( )	( )	( )	( )
Artistic Skills / ความสามารถในด้านศิลป์	( )	( )	( )	( )

Communication Skills / ความสามารถในการสื่อสาร	( )	( )	( )	( )

14.) Please sort the most critical skills to your job / กรุณาเรียงลำดับตามความสำคัญต่องานของคุณ?

_____Analytical and Calculating Skills / ความสามารถในการวิเคราะห์และการคำนวณ

_____Financial Skills / ความสามารถด้านบัญชีและการเงิน

_____Human Relation Skills / ความสามารถในการเข้ากับคนอื่นได้ดี เข้าถึงคน

_____Management and Leadership Skills / ความสามารถในการจัดการ

_____Artistic Skills / ความสามารถในด้านศิลป์

_____Communication Skills / ความสามารถในการสื่อสาร

15.) How necessary are these COMMUNICATION skills for your job? /
ความสามารถทางการสื่อสารเหล่านี้มีความสำคัญมากน้อยเพียงใดต่องานของคุณ?

	Always Need / ขาดความสามารถนี้ไม่ได้	Substantially Need / เป็นความสามารถสำคัญต่องาน	Somewhat Need / ใช้ความสามารถนี้บ้าง	No Need / ไม่จำเป็นต้องใช้ความสามารถนี้
Writing Concise Reports / การเขียนรายงาน กระทัดรัด ได้ใจความ	( )	( )	( )	( )
Writing Technical Work / การเขียนงานที่มีคำศัพท์เฉพาะทาง	( )	( )	( )	( )
Perceiving Non-Verbal Messages / การสังเกตุจากการสื่อสารของผู้อื่น	( )	( )	( )	( )
Expressing Idea / การบอกเล่าความคิดได้ชัดเจน ง่ายต่อการเข้าใจ	( )	( )	( )	( )
Listening Attentively / การรับฟังข้อมูลและเข้าใจได้อย่างรวดเร็ว	( )	( )	( )	( )
Speaking Effectively / การพูดจาสื่อสารที่ชัดเจน	( )	( )	( )	( )
Translating / ความสามารถในการตีความภาษา	( )	( )	( )	( )
Proofreading / การพิสูจน์อักษร ตรวจสอบความถูกต้องเอกสาร	( )	( )	( )	( )
Editing /	( )	( )	( )	( )

การแก้ไขเอกสารให้ถูกต้อง				
Instructing / การสอนงานผู้ฟัง	( )	( )	( )	( )
Acting as Liaison / การเจรจาในฐานะตัวแทนผู้อื่น	( )	( )	( )	( )
Presenting / การนำเสนองาน	( )	( )	( )	( )
Directing / การพูดจาเพื่อมอบหมายงาน	( )	( )	( )	( )
Facilitating Group / การดำเนินการพูดคุยในกลุ่มสัมมนา	( )	( )	( )	( )
Providing Feedback / การให้ความเห็นอย่างสร้างสรรค์	( )	( )	( )	( )
Reporting Information / การรายงานข้อความตามข้อเท็จจริง	( )	( )	( )	( )

16.) How necessary are these GENERAL skills for your job? /
ความสามารถทั่วไปเหล่านี้มีความสำคัญมากน้อยเพียงใดต่องานของคุณ?

	Always Need / ขาดความสามารถนี้ไม่ได้	Substantially Need / เป็นความสามารถสำคัญต่องาน	Substantial Need / ใช้ความสามารถนี้บ้าง	No Need / ไม่จำเป็นต้องใช้ความสามารถนี้
Cooperating with Others / การให้ความร่วมมือกับผู้อื่น	( )	( )	( )	( )
Being Punctual / การตรงต่อเวลาก่อนเวลาที่กำหนด	( )	( )	( )	( )
Managing Time / การจัดตารางเวลา	( )	( )	( )	( )
Attention to Details / ความสนใจในรายละเอียดปลีกย่อย	( )	( )	( )	( )
Meeting Goals / การทำให้สำเร็จตามเป้าหมาย	( )	( )	( )	( )
Setting and Meeting Deadlines / การทำให้เสร็จในเวลาที่กำหนด	( )	( )	( )	( )
Enlisting Help / การสร้างตัวเลือกเพื่อช่วยให้งานสำเร็จ	( )	( )	( )	( )
Accepting Responsibility / การยอมรับหน้าที่ของงาน	( )	( )	( )	( )

17.) How necessary are these ANALYTICAL skills for your job? /
ความสามารถทางการวิเคราะห์เหล่านี้มีความสำคัญมากน้อยเพียงใดต่องานของคุณ?

	Always Need / ขาดความสามารถนี้ไม่ได้	Substantially Need / เป็นความสามารถสำคัญต่องาน	Somewhat Need / ใช้ความสามารถนี้บ้าง	No Need / ไม่จำเป็นต้องใช้ความสามารถนี้
Need Analysis / การวิเคราะห์ความต้องการ	( )	( )	( )	( )
Designing Surveys / การออกแบบแบบสอบถามเพื่อใช้เก็บข้อมูล	( )	( )	( )	( )
Inquiring / การสอบถามหาข้อมูล	( )	( )	( )	( )
Interviewing / การสัมภาษณ์หาข้อมูลจากบุคคล	( )	( )	( )	( )
Observing / การสังเกตุข้อมูลรอบข้าง	( )	( )	( )	( )
Compiling Information / การรวบรวมข้อมูล	( )	( )	( )	( )
Comparing / การเปรียบเทียบข้อมูล	( )	( )	( )	( )
Categorizing / การจัดเป็นกลุ่มหมวดหมู่ ของข้อมูล	( )	( )	( )	( )
Classifying / การรู้จักระบุและแยกแยะข้อมูล เช่น แยกขาวออกจากดำ	( )	( )	( )	( )
Screening / การกรองข้อมูลที่ไม่จำเป็นออกไป	( )	( )	( )	( )
Extracting / การเลือกข้อมูลที่เป็นประโยชน์เท่านั้นมาใช้	( )	( )	( )	( )
Developing Evaluation Strategies / การออกแบบวิธีการประเมิน	( )	( )	( )	( )
Imagining Alternatives / การสร้างทางเลือกในวิธีแก้ปัญหา	( )	( )	( )	( )
Investigating / การตรวจสอบความถูกต้องของข้อมูล	( )	( )	( )	( )
Testing / การทดสอบคุณภาพของข้อมูล	( )	( )	( )	( )

Synthesizing การสังเคราะห์ข้อคิดจากข้อมูล	( )	( )	( )	( )
Diagnosing / การตรวจหาข้อผิดพลาด	( )	( )	( )	( )
Reasoning / การให้เหตุผลที่นำไปสู่ข้อสรุป	( )	( )	( )	( )
Statistics / การหาสถิติเพื่อวิเคราะห์หาข้อสรุป	( )	( )	( )	( )
Forecasting / การคาดเดาข้อมูลหรือเหตุการณ์	( )	( )	( )	( )
Calculating / การคำนวณ	( )	( )	( )	( )
Statistical Modeling / การสร้างโมเดลทางสถิติ	( )	( )	( )	( )

18.) How necessary are these MANAGEMENT skills for your job? /
ความสามารถทางการจัดการเหล่านี้มีความสำคัญมากน้อยเพียงใดต่องานของคุณ?

	Always Need / ขาดความสามารถนี้ไม่ได้	Substantially Need / เป็นความสามารถสำคัญต่องาน	Somewhat Need / ใช้ความสามารถนี้บ้าง	No Need / ไม่จำเป็นต้องใช้ความสามารถนี้
Problem Identification / การตรวจสอบต้นตอปัญหา	( )	( )	( )	( )
Handling Details / การจัดการกับรายละเอียดของข้อมูล	( )	( )	( )	( )
Generating Ideas / การสร้างความคิดใหม่ๆ	( )	( )	( )	( )
Coordinating Tasks / การประสานงานกับผู้อื่น	( )	( )	( )	( )
Managing Group / การจัดการดูแลกลุ่มคน	( )	( )	( )	( )
Managing Conflict / การจัดการกับความขัดแย้ง	( )	( )	( )	( )
Decision Making with Others / การตัดสินใจร่วมกับผู้อื่น	( )	( )	( )	( )
Goal Setting / การกำหนดเป้าหมาย	( )	( )	( )	( )
Setting Priorities / การกำหนดลำดับความสำคัญของงาน	( )	( )	( )	( )
Planning / การวางแผนงาน	( )	( )	( )	( )

Scheduling / การจัดตารางเวลางาน	( )	( )	( )	( )
Budgeting / การจัดการค่าใช้จ่าย	( )	( )	( )	( )
Initiate Change / การริเริ่มการเปลี่ยนแปลง	( )	( )	( )	( )
Promote Change / การผลักดันการเปลี่ยนแปลง	( )	( )	( )	( )
Policy Development / การสร้างนโยบาย	( )	( )	( )	( )
Policy Implementation / การบังคับใช้นโยบาย	( )	( )	( )	( )
Monitoring / การตรวจสอบงานเป็นระยะ	( )	( )	( )	( )
Reporting / การรายงานข้อมูลการดำเนินงาน	( )	( )	( )	( )
Controlling / การดูแลให้งานบรรลุตามเป้าหมาย	( )	( )	( )	( )
Assessing / การประเมินผลงาน	( )	( )	( )	( )
Forecasting / การคาดเดาผลการดำเนินงาน	( )	( )	( )	( )
Supervising / การให้คำแนะนำในการทำงานแก่ลูกน้อง	( )	( )	( )	( )
Delegating Responsibility /การมอบหมายความรับผิดชอบให้ทีมงาน	( )	( )	( )	( )
Teaching or Training / การสอนตัวงานให้ผู้อื่น	( )	( )	( )	( )
Coaching / การสร้างผู้อื่นให้ทำงานได้ดีในสิ่งที่ถนัด	( )	( )	( )	( )
Recruiting / การคัดเลือกบุคคลเข้าในทีมงาน	( )	( )	( )	( )

19.) How necessary are these HUMAN RELATIONS skills for your job? /
ความสามารถในการสร้างสัมพันธ์เหล่านี้มีความสำคัญมากน้อยเพียงใดต่องานของคุณ?

	Always Need / ขาดความสามารถนี้ไม่ได้	Substantially Need / เป็นความสามารถสำคัญต่องาน	Somewhat Need / ใช้ความสามารถนี้บ้าง	No Need / ไม่จำเป็นต้องใช้ความสามารถนี้
Listening / การเป็นผู้ฟังที่ดี	( )	( )	( )	( )

Counseling / การเป็นที่ปรึกษา	( )	( )	( )	( )
Developing Rapport / การสร้างความสัมพันธ์ในเวลาอันสั้น	( )	( )	( )	( )
Cooperating / การร่วมทำงานไปด้วยกันกับผู้อื่น	( )	( )	( )	( )
Perceiving Feelings / การรับรู้ความรู้สึกของผู้อื่น	( )	( )	( )	( )
Providing Support for Others / การสนันสนุนผู้อื่น	( )	( )	( )	( )
Representing Others / การเป็นตัวแทนของผู้อื่น	( )	( )	( )	( )
Sharing Credit / การกล่าวถึงผลงานของผู้ร่วมงานคนอื่น	( )	( )	( )	( )
Asserting / การปกป้องสิทธิหรือความคิดของตัวเองอย่างเหมาะสม	( )	( )	( )	( )
Conveying Feelings / การอธิบายความรู้สึกให้ผู้อื่น	( )	( )	( )	( )
Serving / การให้บริการผู้อื่น	( )	( )	( )	( )
Motivating / การหาแรงจูงใจให้ผู้อื่นทำงานที่กำหนด	( )	( )	( )	( )
Persuading / การพูดจาให้คนคล้อยตาม	( )	( )	( )	( )
Influencing / การหาวิธีการที่ทำให้ผู้อื่นทำตามที่ต้องการ	( )	( )	( )	( )
Negotiating / การเจรจาต่อรองกับผู้อื่น	( )	( )	( )	( )
Leading / การเป็นผู้นำ	( )	( )	( )	( )
Demonstrating / การทำให้เห็นเป็นตัวอย่าง	( )	( )	( )	( )

20.) How necessary are these FINANCIAL skills for your job? /
ความสามารถทางการเงินเหล่านี้มีความสำคัญมากน้อยเพียงใดต่องานของคุณ?

	Always Need / ขาดความสามารถนี้ไม่ได้	Substantially Need / เป็นความสามารถสำคัญต่องาน	Somewhat Need / ใช้ความสามารถนี้บ้าง	No Need / ไม่จำเป็นต้องใช้ความสามารถนี้
Record Keeping / การบันทึกข้อมูล	( )	( )	( )	( )
Calculating / การคำนวณบัญชี	( )	( )	( )	( )
Auditing / การตรวจสอบความถูกต้อง	( )	( )	( )	( )

Financial Planning / การวางแผนการเงิน	( )	( )	( )	( )
Investing / การคำนวญการลงทุน	( )	( )	( )	( )
Inventory Control / การควบคุมสินค้า	( )	( )	( )	( )
Cost Analysis / การวิเคราะห์ต้นทุน	( )	( )	( )	( )

21.) How necessary are these ARTISTIC skills for your job? /
ความสามารถทางศิลปะเหล่านี้มีความสำคัญมากน้อยเพียงใดต่องานของคุณ?

	Always Need / ขาดความสามารถนี้ไม่ได้	Substantially Need / เป็นความสามารถสำคัญต่องาน	Somewhat Need / ใช้ความสามารถนี้บ้าง	No Need / ไม่จำเป็นต้องใช้ความสามารถนี้
Decorating / การตกแต่ง	( )	( )	( )	( )
Displaying / การนำเสนอ	( )	( )	( )	( )
Drawing / การวาดรูป	( )	( )	( )	( )
Designing / การออกแบบ	( )	( )	( )	( )
Illustrating / การสร้างให้เห็นด้วยรูปภาพ	( )	( )	( )	( )
Painting / การทาสี	( )	( )	( )	( )
Sculpting / การปั้น	( )	( )	( )	( )
Graphic Arts / การออกแบบกราฟิค	( )	( )	( )	( )
Crafts / การสร้างงานศิลปะด้วยมือ	( )	( )	( )	( )
Acting / การแสดง	( )	( )	( )	( )
Singing / การร้องเพลง	( )	( )	( )	( )
Dancing / การเต้น	( )	( )	( )	( )
Photography / การถ่ายรูป	( )	( )	( )	( )
Calligraphy / การออกแบบตัวอักษร	( )	( )	( )	( )
Playing an Instrument / การใช้เครื่องดนตรี	( )	( )	( )	( )
Visualizing / การสร้างให้เห็นภาพ	( )	( )	( )	( )
Coloring / การเลือกใช้สี	( )	( )	( )	( )

Appendix A2: Online Questionnaire Questions for Creating Dynamic Associations between skills and concepts

Section 1: About yourself

1.) Your age?

2.) Your nationality?

3.) What is your highest degree?

( ) Doctoral Degree

( ) Master Degree

( ) Bachelor Degree

( ) High School

( ) Middle School

( ) Primary School

4.) Have you had any working experience outside the academia (excluding internships and part time jobs)?

( ) Yes

( ) No

5.) What are your five most important values?

[ ] Achievement (Sense of accomplishment)

[ ] Advancement (Moving forward in your career through promotion)

[ ] Adventure (Involving with risk taking)

[ ] Aesthetics (Appreciating the beauty of ides, things, etc.,)

[ ] Autonomy (Working independently)

[ ] Caring (Love, Affection)

[ ] Challenge (Stimulating full use of your potential)

[ ] Change and Variety (Frequent work responsibilities)

[ ] Competition (Pitting your abilities against others where there is clear win and lose outcomes)

[ ] Cooperation (Working as a team)

[ ] Creativity (Being imaginative)

[ ] Economic Security (Having enough money)

[ ] Excitement (Experiencing frequent excitement in your work)

[ ] Family Happiness (Being able to spend time with family)

[ ] Friendship (Developing a close personal relationship)

[ ] Health (Physical well being)

[ ] Help Others (Involving with in helping people)

[ ] Help Society (Doing something to contribute to the betterment of the world)

[ ] Inner Harmony (Being a peace with oneself)

[ ] Integrity (Sincerity and honesty)

[ ] Intellectual Status (Being regarded as as an expert in the field)

[ ] Knowledge (Understanding though study and experience)

[ ] Leadership (Influence over others)

[ ] Leisure (Having time for hobbies, sports, activities and interests)

[ ] Loyalty (Steadfastness and allegiance)

[ ] Pleasure (Enjoyment)

[ ] Power (Authority)

[ ] Precision (Working with situations where there is little tolerance for error)

[ ] Responsibility (Being Accountable for the result)

[ ] Recognition (Getting acknowledge for your contribution)

[ ] Stability (Not like to change over a long time period of time)

[ ] Spirituality

[ ] Time Freedom (Working on your own schedule)

[ ] Wealth (Profit, Making a lot of money)

[ ] Wisdom (Understanding based on accumulation of knowledge)

Section 2: About your organization

6.) What industry is your organization?

( ) Accounting

( ) Advertising

( ) Aerospace / Aviation

( ) Automotive

( ) Agriculture / Forestry / Fishing

( ) Biotechnology

( ) Hotels and Lodging Places

( ) Computers (Hardware, Desktop Software)

( ) Communications

( ) Construction / Home Improvement

( ) Consulting

( ) Education

( ) Engineering / Architecture

( ) Entertainment / Recreation

( ) Finance / Banking / Insurance

( ) Food Service

( ) Government / Military

( ) Healthcare / Medical

( ) Internet

( ) Legal

( ) Manufacturing

( ) Marketing / Market Research / Public Relations

( ) Media / Printing / Publishing

( ) Mining

( ) Non-Profit

( ) Pharmaceutical / Chemical

( ) Research / Science

( ) Real Estate

( ) Retail

( ) Telecommunications

( ) Transportation and Distribution

( ) Utilities

( ) Wholesale

( ) Professional Services

( ) Other

( ) Don't work

7.) Your organization size worldwide (in person)?

( ) 1

( ) 2-4

( ) 5-9

( ) 10-19

( ) 20-99

( ) 100-499

( ) 500-9,999

( ) 10,000+

Section 3: About your current (or most recent) job

8.) Your specific job function?

( ) Accounting

( ) Administration

( ) Advertisement/PR

( ) Architecture

( ) Arts/Leisure

( ) Banking

( ) Beauty/Fashion

( ) Buying/Purchasing

( ) Clerical/Reception

( ) Computer Hardware

( ) Computer Software / Programming

( ) Construction

( ) Consulting

( ) Customer Service

( ) Design

( ) Distribution

( ) Education

( ) Entertainment

( ) Finance

( ) Health Care (Physical and Mental)

( ) Human resources management

( ) Logistics

( ) Management (Senior/Corporate)

( ) News/Information

( ) Operations

( ) Planning (Meeting, Events, etc.)

( ) Production

( ) Real Estate

( ) Research

( ) Restaurant/Food service

( ) Sales/Marketing

( ) Science/Technology

( ) Social service

( ) Student

( ) Other

( ) N/A-Unemployed/Retired/Homemaker

9.) Your job level?

( ) Top Level Executive

( ) Senior Vice President

( ) Vice President

( ) Director

( ) Manager

( ) Supervisor

( ) Team Lead

( ) Senior Professional

( ) Professional

( ) Administrative/Support personnel

( ) N/A- Unemployed/Retired/Homemaker

10.) Your specific job title?

11.) A brief of your job description?

12.) Your monthly salary in US dollars (before tax)?

( ) $0 - $250

( ) $251 - $500

( ) $501 - $750

( ) $751 - $1,000

( ) $1,001 - $1,500

( ) $1,501 - $2,000

( ) $2,001- $2,500

( ) $2,501- $3,500

( ) $3,501- $5,000

( ) $5,001- $6,500

( ) $6,500 - $8,000

( ) $8,001 - $10,000

( ) $10,001 or higher

13.) How satisfied are you with your current (or most recent) job?

( ) Very Satisfied

( ) Satisfied

( ) Neutral

( ) Dissatisfied

( ) Very Dissatisfied

Section 3: About your academia

14.) What major are you currently studying?

( ) ---- Area, Ethnic, Cultural, & Gender Studies ----

( ) African Studies

( ) African-American Studies

( ) American Studies

( ) Asian American Studies

( ) East Asian Studies

( ) German Studies

( ) Hispanic-American Studies

( ) Native American Studies

( ) Near/Middle Eastern Studies

( ) Women's Studies

( ) ---- Arts, Visual & Performing ----

( ) Art History/Criticism/Conservation

( ) Arts - General

( ) Drama/Theater Arts

( ) Fine/Studio Arts

( ) Music - General

( ) ---- Biological & Biomedical Sciences ----

( ) Biochemistry

( ) Biology

( ) Evolutionary Biology

( ) Neurobiology/Physiology

( ) ---- Communications & Journalism ----

( ) Communications/Rhetoric

( ) ---- Computer & Information Sciences ----

( ) Computer Science

( ) Computer/Information Sciences - General

( ) ---- Engineering ----

( ) Chemical Engineering

( ) Civil Engineering

( ) Electrical/Communications Engineering

( ) Engineering - General

( ) Environmental Engineering

( ) Materials Engineering

( ) Materials Science

( ) Mechanical Engineering

( ) Petroleum
( ) ---- Engineering Technologies ----
( ) Engineering/Industrial Management
( ) ---- English Language & Literature ----
( ) English Composition
( ) English Language & Literature - General
( ) English Literature (British)
( ) ---- Foreign Language & Literature ----
( ) Chinese
( ) Classics
( ) Comparative Literature
( ) French
( ) German
( ) Greek, Ancient
( ) Italian
( ) Japan
( ) Latin
( ) Linguistics
( ) Romance Languages
( ) Sanskrit/Classical Indian
( ) Slavic
( ) Spanish
( ) ---- History ----
( ) History - General
( ) History of Science/Technology
( ) ---- Liberal Arts & Sciences ----
( ) Humanities
( ) Liberal Arts & Sciences
( ) ---- Mathematics ----
( ) Applied Mathematics
( ) Mathematics - General
( ) Statistics
( ) -- Multi/Interdisciplinary Studies --
( ) Classical/Ancient Mediterranean/Near Eastern Studies
( ) Global Studies
( ) Intercultural/Multicultural/Diversity Studies
( ) Science, Technology & Society
( ) Systems Science/Theory
( ) ---- Natural Resources & Conservation ----
( ) Environmental Studies
( ) ---- Philosophy & Religion ----
( ) Philosophy

( ) Religion/Religious Studies

( ) ---- Physical Sciences ----

( ) Atomic/Molecular Physics

( ) Chemistry

( ) Geology

( ) Physics

( ) ---- Psychology ----

( ) Psychology - General

( ) ---- Public Administration & Services ----

( ) Public Policy Analysis

( ) ---- Social Sciences ----

( ) Anthropology

( ) Archaeology

( ) Economics

( ) International Relations

( ) Political Science/Government

( ) Social Sciences - General

( ) Sociology

( ) Urban Studies

15.) How satisfied are you with your student life?

( ) Very Satisfied

( ) Satisfied

( ) Neutral

( ) Dissatisfied

( ) Very Dissatisfied

16.) How difficult do you find the class lectures in your study program?

( ) Very Easy to follow

( ) Easy to follow

( ) Neutral

( ) Difficult to follow

( ) Very Difficult to follow

Section 4: Critical skills needed for your job or study

17.) How critical are these skill groups to your job?

Guideline for determining the skill criticality to a job

If the skill DIRECTLY enhances the overall job performance, rate criticality as "Indispensable"

If the skill INDIRECTLY influences the job performance, rate criticality as "Necessary"

If the skill has LITTLE influence on the job performance, rate criticality as "Somewhat necessary"

If the skill has NO influence on the job performance, rate criticality as "Not necessary at all"

	Indispensable	Necessary	Somewhat necessary	Not necessary at all
Analytical and Calculating Skills	( )	( )	( )	( )
Management and Leadership Skills	( )	( )	( )	( )
Human Relation Skills	( )	( )	( )	( )

Financial Skills	( )	( )	( )	( )
Artistic Skills	( )	( )	( )	( )
Communication Skills	( )	( )	( )	( )

18.) Please rearrange the list starting from the most critical skill to your job

_____Analytical and Calculating Skills

_____Management and Leadership Skills

_____Human Relation Skills

_____Financial Skills

_____Artistic Skills

_____Communication Skills

Concept 1: Algebra and Number Theory

19.) How critical is the concept of Algebra and Number Theory to your job?

Guideline for determining the frequency of the concept use in a job

Always: Use the knowledge concept in your job every day

Often: Use the knowledge concept in your job periodically (i.e., weekly, monthly)

Sometimes: Rarely use the knowledge concept in your job (i.e., once in a big while)

Never: Never use the knowledge concept in your job

Guideline for determining the concept criticality to a job

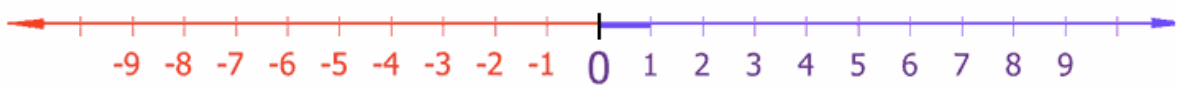
If the understanding of the knowledge concept SERIOUSLY impacts the overall job performance, rate the criticality as "Indispensable"; Without this knowledge concept, there is no other way to complete the job

If the understanding of the knowledge concept IMPROVES the overall job performance, rate the criticality as "Necessary"; Without this knowledge concept, there is another way to get around to complete the job

If the understanding of the knowledge concept is RELEVANT to the job, rate the criticality as "Somewhat necessary"; Without this knowledge concept, there are plenty alternatives to finish the job

If the understanding of the knowledge concept is IRRELEVANT to the job, rate the criticality as "Not necessary at all"

	The frequency of the concept use in your job				The concept criticality to your job			
	Always	Often	Sometimes	Never	Indispensable	Necessary	Somewhat necessary	Not necessary at all
The concept of Algebra and Number Theory	( )	( )	( )	( )	( )	( )	( )	( )



http://upload.wikimedia.org/wikipedia/commons/0/09/Number-line.gif

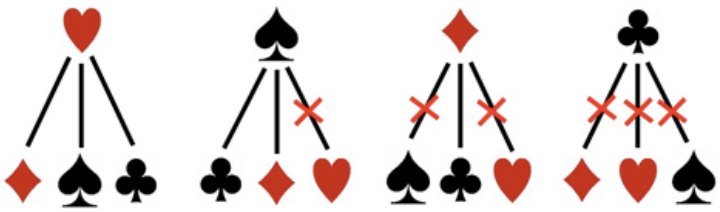
Some sub concepts in the Algebra and Number Theory in this context are:

- The structure of the natural, integer, rational, real, and complex number systems and its basic operations (+, - , x and ÷)
- Ratio, proportion, percent, and average (including arithmetic mean and weighted average)
- The properties of counting numbers (e.g., prime, composite, prime factorization, even, odd, factors, multiples)

Concept 2: Permutation and Combination

20.) How critical is the concept of Permutation and Combination to your job?

	The frequency of the concept use in your job				The concept criticality to your job			
	Always	Often	Sometimes	Never	Indispensable	Necessary	Somewhat necessary	Not necessary at all
The concept of Permutation and Combination	( )	( )	( )	( )	( )	( )	( )	( )



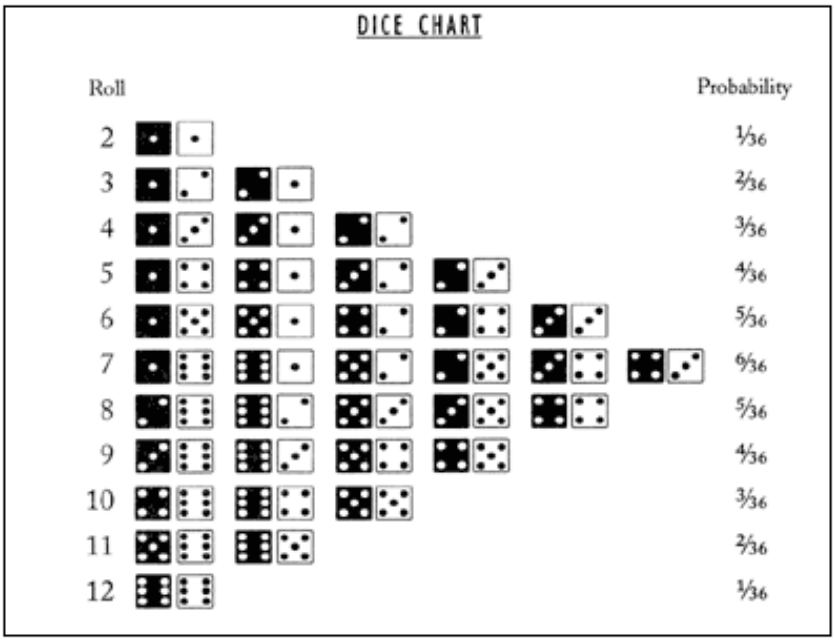
http://edubuzz.org/blogs/advhigherthings/files/2008/09/combinationalcards.jpg

A k-combination of a finite set S is a subset of k distinct elements of S. Specifying a subset does not arrange them in a particular order; by contrast, producing the k distinct elements in a specific order defines a sequence without repetition, also called k-permutation (but which is not a permutation of S in the usual sense of that term).

Concept 3: Probability

21.) How critical is the concept of Probability to your job?

	The frequency of the concept use in your job				The concept criticality to your job			
	Always	Often	Sometimes	Never	Indispensable	Necessary	Somewhat necessary	Not necessary at all
The concept of Probability	( )	( )	( )	( )	( )	( )	( )	( )



http://www.onlinecraps.net/images/craps-probability-chart.jpg

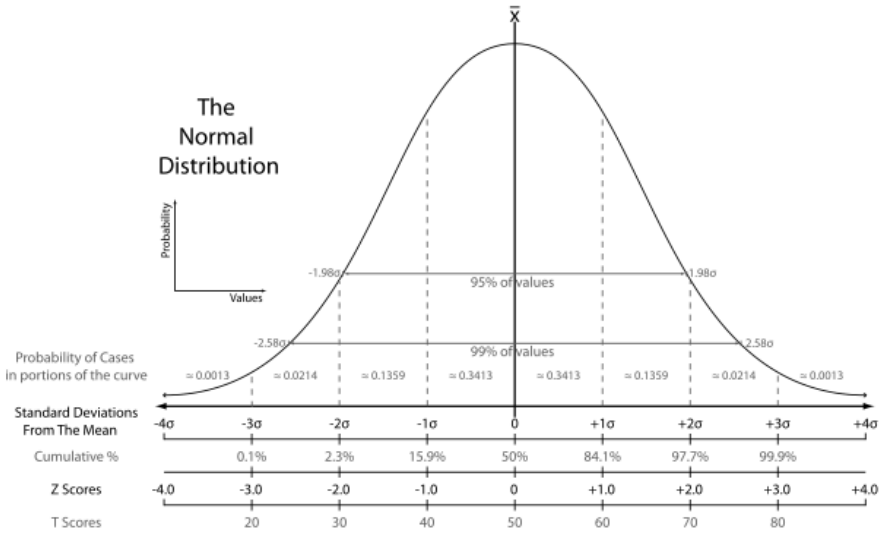
Some sub-concepts in the Probability in this context are:

- Sample space and probability distribution
- Conditional probability and independent events
- Compute and interpret the expected value of random variables

Concept 4: Statistics

22.) How critical is the concept of Statistics to your job?

	The frequency of the concept use in your job				The concept criticality to your job			
	Always	Often	Sometimes	Never	Indispensable	Necessary	Somewhat necessary	Not necessary at all
The concept of Statistics	( )	( )	( )	( )	( )	( )	( )	( )



http://upload.wikimedia.org/wikipedia/commons/2/25/The_Normal_Distribution.svg

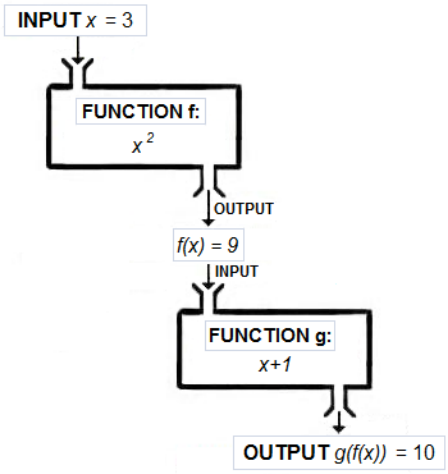
Some sub-concepts in the Statistics in this context are:

- Normal distributions and their characteristics (e.g., mean, standard deviation)
- Sampling distributions
- The role of randomization in surveys and experiments

Concept 5: Functions

23.) How critical is the concept of Functions to your job?

	The frequency of the concept use in your job				The concept criticality to your job			
	Always	Often	Sometimes	Never	Indispensable	Necessary	Somewhat necessary	Not necessary at all
The concept of Functions	( )	( )	( )	( )	( )	( )	( )	( )



http://upload.wikimedia.org/wikipedia/en/3/32/Function_machine5.png

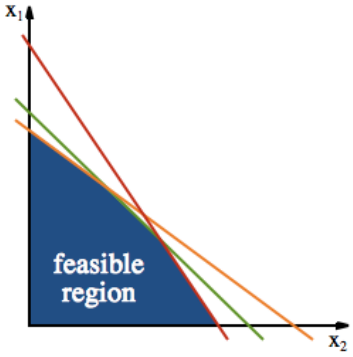
Some sub-concepts in the Functions in this context are:

- Domain
- Range
- Composite Function
- Inverse Function
- Constant Function f(x) = a
- Linear Function f(x) = ax + b
- Quadratic Function f(x) = ax2 + bx + c
- Exponential
- Logarithm

Concept 6: Linear Programming

24.) How critical is the concept of Linear Programming to your job?

	The frequency of the concept use in your job				The concept criticality to your job			
	Always	Often	Sometimes	Never	Indispensable	Necessary	Somewhat necessary	Not necessary at all
The concept of Linear Programming	( )	( )	( )	( )	( )	( )	( )	( )



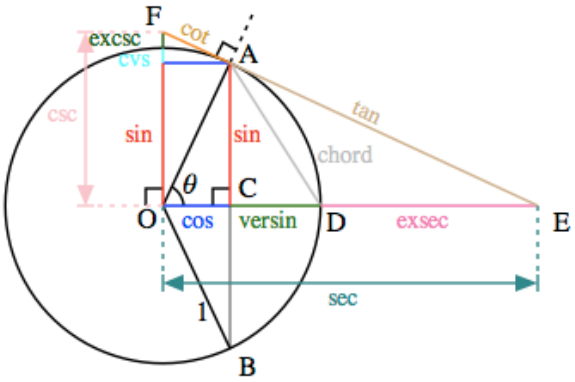
http://upload.wikimedia.org/wikipedia/commons/0/0c/Linear_Programming_Feasible_Region.svg

Linear programming (LP) is a mathematical method for determining a way to achieve the best outcome (such as maximum profit or lowest cost) in a given mathematical model for some list of requirements represented as linear equations -- Wikipedia

Concept 7: Trigonometry

25.) How critical is the concept of Trigonometry to your job?

	The frequency of the concept use in your job				The concept criticality to your job			
	Always	Often	Sometimes	Never	Indispensable	Necessary	Somewhat necessary	Not necessary at all
The concept of Trigonometry	( )	( )	( )	( )	( )	( )	( )	( )



http://upload.wikimedia.org/wikipedia/commons/9/9d/Circle-trig6.svg

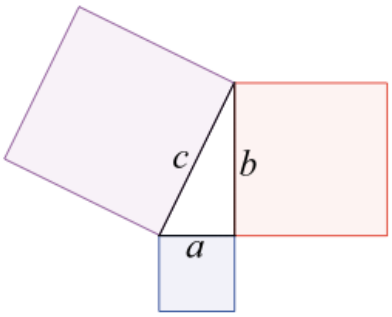
Some sub-concepts in the Trigonometry in this context are:

- The law of sines and the law of cosines
- Converting between rectangular and polar coordinate systems

Concept 8: Geometry

26.) How critical is the concept of Geometry to your job?

	The frequency of the concept use in your job				The concept criticality to your job			
	Always	Often	Sometimes	Never	Indispensable	Necessary	Somewhat necessary	Not necessary at all
The concept of Geometry	( )	( )	( )	( )	( )	( )	( )	( )



http://upload.wikimedia.org/wikipedia/commons/d/d2/Pythagorean.svg

Some sub-concepts in the Geometry in this context are:

- Pythagorean Theorem and its Converse
- Point
- Locus
- Line
- Parallel
- Angle

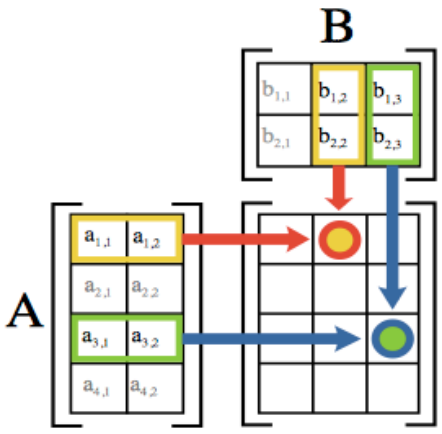
Full list can be retrieved from

http://en.wikipedia.org/wiki/List_of_geometry_topics#Euclidean_geometry.2C_foundations

Concept 9: Matrix

27.) How critical is the concept of Matrix to your job?

	The frequency of the concept use in your job				The concept criticality to your job			
	Always	Often	Sometimes	Never	Indispensable	Necessary	Somewhat necessary	Not necessary at all
The concept of Matrix	( )	( )	( )	( )	( )	( )	( )	( )



http://upload.wikimedia.org/wikipedia/en/e/eb/Matrix_multiplication_diagram_2.svg

Some sub-concepts in the Matrix in this context are:

- Basic Operations (e.g., Addition, Scalar Multiplication, Transpose)
- Matrix Multiplication, Linear Equations and Linear Transformations

Concept 10: Vector

28.) How critical is the concept of Vector to your job?

	The frequency of the concept use in your job				The concept criticality to your job			
	Always	Often	Sometimes	Never	Indispensable	Necessary	Somewhat necessary	Not necessary at all
The concept of Vector	( )	( )	( )	( )	( )	( )	( )	( )

http://upload.wikimedia.org/wikipedia/commons/e/e6/Vector_addition3.svg

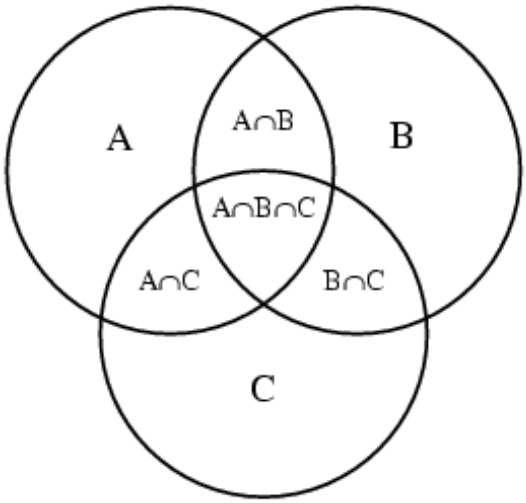
Some sub-concepts in the Vector in this context are:

- Scalar Multiplication
- Linear Combination
- Linear Span
- Linear Independence
- Coordinates Vector

Concept 11: Set Theory

29.) How critical is the concept of Set Theory to your job?

	The frequency of the concept use in your job				The concept criticality to your job			
	Always	Often	Sometimes	Never	Indispensable	Necessary	Somewhat necessary	Not necessary at all
The concept of Set Theory	( )	( )	( )	( )	( )	( )	( )	( )



http://java.sun.com/developer/onlineTraining/collections/images/venn.gif

Some sub-concepts in the Set Theory in this context are:

- Union
- Intersection
- Complement
- Symmetric Difference
- Power Set
- Subset

Concept 12: Boolean Algebra (Logic)

30.) How critical is the concept of Boolean Algebra (Logic) to your job?

	The frequency of the concept use in your job				The concept criticality to your job			
	Always	Often	Sometimes	Never	Indispensable	Necessary	Somewhat necessary	Not necessary at all
The concept of Boolean Algebra (Logic)	( )	( )	( )	( )	( )	( )	( )	( )

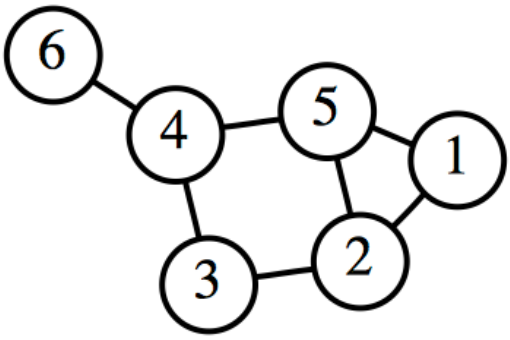
A	*B*	*A* OR *B*	*A* AND *B*	NOT *A*
True	True	True	True	False
True	Unknown	True	Unknown	False
True	False	True	False	False
Unknown	True	True	Unknown	Unknown
Unknown	Unknown	Unknown	Unknown	Unknown
Unknown	False	Unknown	False	Unknown
False	True	True	False	True
False	Unknown	Unknown	False	True
False	False	False	False	True

http://en.wikipedia.org/wiki/Ternary_logic

Concept 13: Graph Theory

31.) How critical is the concept of Graph Theory to your job?

	The frequency of the concept use in your job				The concept criticality to your job			
	Always	Often	Sometimes	Never	Indispensable	Necessary	Somewhat necessary	Not necessary at all
The concept of Graph Theory	( )	( )	( )	( )	( )	( )	( )	( )



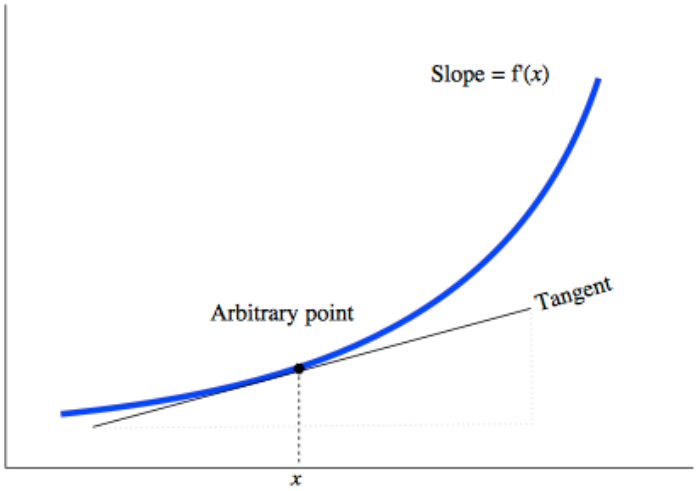
http://upload.wikimedia.org/wikipedia/commons/5/5b/6n-graf.svg

Graph theory is the study of graphs: mathematical structures used to model pairwise relations between objects from a certain collection. A "graph" in this context refers to a collection of vertices or 'nodes' and a collection of edges that connect pairs of vertices. -- Wikipedia

Concept 14: Calculus

32.) How critical is the concept of Calculus to your job?

	The frequency of the concept use in your job				The concept criticality to your job			
	Always	Often	Sometimes	Never	Indispensable	Necessary	Somewhat necessary	Not necessary at all
The concept of Calculus	( )	( )	( )	( )	( )	( )	( )	( )



http://upload.wikimedia.org/wikipedia/commons/d/d4/Tangent_derivative_calculusdia.svg

Some sub-concepts in the Calculus in this context are:

- Limit of Functions
- Series
- Continuity and Differentiability
- Derivatives and Integrals
- The Mean Value Theorem
- The Fundamental Theorem of Calculus

LAST PAGE: Relationship between Math concepts and skills

33.) Can these knowledge concepts help you do the following activities better (i.e., faster, more easily, more accurately)?

- Check the box if yes

- Leave it unchecked if no (including not applicable)

You can interpret the first checkbox as "the concepts in Algebra and Number Theory help me do Problem Identification more easily or accurately".

	Problem Identification	Handling Details	Generating Ideas	Setting Goal	Setting Priorities	Planning	Budgeting	Auditing	Financial Planning	Investing	Inventory Control	Assessing	Forecasting

Algebra and Number Theory	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Permutation and Combination	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Probability	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Statistics	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Functions	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Linear Programming	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Trigonometry	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Geometry	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Matrix	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Vector	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Set Theory	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Boolean Algebra (Logic)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Graph Theory	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Calculus	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

34.) Can these knowledge concepts help you do the following activities better (this continues from previous question)?

- Check the box if yes

- Leave it unchecked if no (including not applicable)

You can interpret the first checkbox as "the concepts in Algebra and Number Theory help me do Need Analysis more easily or accurately".

	Need Analysis	Designing Surveys	Observing	Comparing Data	Categorizing Data	Screening Data	Extracting Data	Developing Evaluation Strategies	Imagining Alternatives	Testing	Synthesizing	Reasoning
Algebra and Number Theory	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Permutation and Combination	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Probability	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Statistics	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Functions	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Linear Programming	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Trigonometry	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Geometry	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Matrix	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Vector	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Set Theory	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Boolean Algebra (Logic)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Graph Theory	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Calculus	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

Appendix B1: Online Questionnaire Questions for Validating Defined Hypothesis (Before Students Use Prototype)

1.) Your school name ? / ชื่อโรงเรียน

( ) สถาบันกวดวิชา BTS

( ) กรุงเทพคริสเตียนวิทยาลัย

( ) ไชยฉิมพลีวิทยาคม

( ) ดอนเมืองทหารอากาศบำรุง

( ) ทวีธาภิเศก 2

( ) ทีปังกรวิทยาพัฒน์(ทวีวัฒนา)ในพระราชูถัมภ์ฯ

( ) ทีปังกรวิทยาพัฒน์(วัดน้อยใน)ในพระราชูปถัมภ์ฯ

( ) นวมินทราชินูทิศ เบญจมราชาลัย

( ) นวมินทราชินูทิศ สตรีวิทยา พุทธมณฑล

( ) นวลนรดิศวิทยาคม รัชมังคลาภิเษก

( ) บางปะกอกวิทยาคม

( ) ปัญญาวรคุณ

( ) ประภามนตรี 2

( ) พญาไท

( ) พิทยาลงกรณ์พิทยาคม

( ) พิบูลประชาสรรค์

( ) พุทธจักรวิทยา

( ) มหรรณพาราม

( ) มัธยมวัดนายโรง

( ) โยธินบูรณะ

( ) ราชดำริ

( ) ราชวินิต

( ) วัดบวรมงคล

( ) วัดประดู่ในทรงธรรม

( ) วัดปากน้ำวิทยาคม

( ) วัดรางบัว

( ) วัดราชบพิธ

( ) วัดราชโอรส

( ) วัดโสมนัส

( ) ศึกษานารี

( ) สวนกุหลาบวิทยาลัย

( ) สารวิทยา

( ) สิริรัตนาธร

( ) อนุบาลสามเสนฯ

( ) อัสสัมชัญธนบุรี

( ) อำนวยศิลป์

( ) อื่น ๆ / Other

2.) Your student ID (Use National ID number if inapplicable)? / รหัสประจำตัวนักเรียนของโรงเรียน (ถ้าไม่มีให้ใช้เลขประจำตัวประชาชน)?

3.) How old are you? / อายุปัจจุบัน

4.) Gender? / เพศ

( ) Male / ชาย

( ) Female / หญิง

5.) What grade are you in? / คุณเรียนอยู่ระดับชั้นไหน

( ) Less than grade 9 / ต่ำกว่ามัธยมศึกษาปีที่ 3

( ) Grade 9 / มัธยมศึกษาปีที่ 3

( ) Grade 10 / มัธยมศึกษาปีที่ 4

( ) Grade 11 / มัธยมศึกษาปีที่ 5

( ) Grade 12 / มัธยมศึกษาปีที่ 6

( ) More than grade 12 / สูงกว่ามัธยมศึกษาปีที่ 6

6.) Your current GPA? / เกรดสะสมปัจจุบัน?

For example, 3.13 / ยกตัวอย่างเช่น 3.13

7.) What is your favorite subject? / วิชาที่ชื่นชอบที่สุด?

( ) Mathematics / คณิต

( ) Physic / ฟิสิกส์

( ) Chemistry / เคมี

( ) Biology / ชีวะ

( ) Social / สังคม

( ) Business / ธุรกิจ

( ) Language (i.e., Thai, English, French) / ภาษา

( ) Art / ศิลปะ

( ) Life Skill / การงานพื้นฐานอาชีพ

8.) How frequent do you do the following actions? / ฉันทำสิ่งต่างๆเหล่านี้บ่อยเพียงใด
(โปรดตอบตามประสบการณ์จริงของตัวเอง)

	Never / ไม่เคยทำเลย	Sometimes / ทำบ้างเป็นบางครั้ง	Most of the times / ทำอยู่บ่อยๆ	Always / ทำอย่างสม่ำเสมอ
I focus on the lessons in classes / ฉันตั้งใจเรียนในห้องเรียนแม้ว่ามันจะไม่น่าสนใจ	( )	( )	( )	( )
I finish my homework / ฉันทำการบ้านเสร็จครบถ้วน	( )	( )	( )	( )
I raise up my hand to answer questions in the classroom / ฉันยกมือตอบคำถามเวลาที่อาจารย์ถาม	( )	( )	( )	( )
I try different learning strategies when I have learning difficulties / ฉันค้นคว้าด้วยตัวเองจนกว่าฉันจะเข้าใจเวลาฉันไม่เข้าใจในสิ่งที่เรียน	( )	( )	( )	( )
I consult friends when I have learning difficulties / ฉันปรึกษาเพื่อนเวลาที่ฉันรู้สึกว่าบทเรียนนั้นยาก	( )	( )	( )	( )
I consult teachers when I have learning difficulties / ฉันปรึกษาอาจารย์เวลาที่ฉันรู้สึกว่าบทเรียนนั้นยาก	( )	( )	( )	( )
I recheck my homework to ensure accuracy / ฉันตรวจสอบการบ้านเพื่อความถูกต้อง	( )	( )	( )	( )

I tend to study harder when I get a bad test score / ฉันขยันหาความรู้เพิ่มเติมมากขึ้นเวลาที่ฉันทำคะแนนได้ไม่ดี	( )	( )	( )	( )
I prepare for exams / ฉันเตรียมตัวก่อนสอบอย่างสม่ำเสมอ	( )	( )	( )	( )
I review the learning materials outside the classroom / ฉันทบทวน "บทเรียน" เพิ่มเติมนอกห้องเรียน	( )	( )	( )	( )
I set time for reviewing learning materials / ฉันกำหนดเวลาอ่านหนังสือไว้เป็นอย่างดี	( )	( )	( )	( )
I surf the Internet to expand my academic knowledge base / ฉันหาข้อมูลทางอินเตอร์เนทเพื่อเพิ่มฐานความรู้ของฉัน	( )	( )	( )	( )
I read supplementary books to enrich my understanding of class materials / ฉันอ่าน "หนังสือนอกเวลา" เพื่อเพิ่มความเข้าใจกับสิ่งที่ฉันเรียนในห้อง	( )	( )	( )	( )
I seek for activities inside and outside schools to help me learn / ฉันหากิจกรรมต่างๆที่จะช่วยสร้างเสริมประสบการณ์ของฉัน	( )	( )	( )	( )
I plan my study myself / ฉันวางแผนการเรียนด้วยตัวฉันเอง	( )	( )	( )	( )
I like to do assignments in group / ฉันชอบทำงานเป็นกลุ่ม	( )	( )	( )	( )
I like the social relationships in academic work / ฉันชอบมิตรภาพที่ได้จากการทำงานกลุ่มที่โรงเรียน	( )	( )	( )	( )
I have interest in a number of academic topics / ฉันสนใจเรียนในแทบทุกรายวิชา	( )	( )	( )	( )
I think about my values when I have conflicts about time to be spent on achieving / ฉันเลือกทำในสิ่งที่สำคัญต่อตัวฉันที่สุด เวลาที่ฉันคิดอยากทำหลายๆอย่างพร้อมกัน	( )	( )	( )	( )
I enjoy intellectual challenges / ฉันชอบแก้โจทย์ปัญหาที่ยากและท้าทายความสามารถ	( )	( )	( )	( )
I am interested in solving a problem set with which others have difficulties / ฉันสนใจที่จะแก้โจทย์ปัญหาที่เพื่อนๆคนอื่นทำไม่ได้	( )	( )	( )	( )
I set myself realistic but challenging goals / ฉันตั้งเป้าหมายในการเรียนของฉันไว้สูงและสามาร	( )	( )	( )	( )

ถทำได้				

9.) How much do you agree with the following statements? / ฉันเห็นด้วยกับข้อความเหล่านี้มากน้อยเพียงใด (โปรดตอบตามความรู้สึกจริงของตัวเอง)

	Disagree / ไม่เห็นด้วย	Somewhat Agree/ ค่อนข้างเห็นด้วย	Agree / เห็นด้วย	Strongly Agree / เห็นด้วยอย่างยิ่ง
I feel that I study hard / ฉันรู้สึกว่าฉันเรียนหนังสือหนัก	( )	( )	( )	( )
I want to skip some boring classes although I know it helps me develop skills / ฉันอยากโดดเรียนวิชาที่ฉันว่าน่าเบื่อแม้ว่าสิ่งที่เรียนในวิชานั้นจะช่วยพัฒนาความสามารถของฉัน	( )	( )	( )	( )
Learning do not hold my attention at all / การเรียนหนังสือไม่เคยทำให้ฉันมีความสนใจเลย	( )	( )	( )	( )
I feel that I love learning / ฉันรู้สึกรักการเรียนหนังสือ	( )	( )	( )	( )
I see the value of the knowledge concepts / ฉันเห็นคุณค่าขององค์ความรู้ต่างๆ	( )	( )	( )	( )
I understand how the knowledge concepts develop my skills / ฉันเข้าใจว่าองค์ความรู้สามารถพัฒนาให้ฉันมีทักษะต่างๆได้อย่างไร	( )	( )	( )	( )
I understand why I need to learn / ฉันเข้าใจดีว่าเหตุใดฉันจำเป็นต้องเรียนรู้	( )	( )	( )	( )
Learning is fun to do / การเรียนหนังสือเป็นสิ่งที่สนุก	( )	( )	( )	( )
I see the value of education / ฉันเห็นคุณค่าของการศึกษา	( )	( )	( )	( )
I believe that I can do everything If I intend to do / ฉันเชื่อว่าฉันทำได้ทุกอย่างถ้าฉันตั้งใจ	( )	( )	( )	( )
I would describe learning as very interesting / ฉันพูดได้ว่าการเรียนเป็นสิ่งที่น่าสนใจ	( )	( )	( )	( )
If I get a scholarship, I will to pursue a Phd degree although it will takes 6 years to complete / ถ้าฉันได้ทุน ฉันอยากจะเรียนต่อให้ถึงปริญญาเอกแม้ว่าจะต้องใช้เวลาถึง 6 ปี	( )	( )	( )	( )
I enjoyed learning very much / ฉันสนุกกับการเรียนหนังสือมากๆ	( )	( )	( )	( )
I will change my learning behavior for better future / ฉันจะเปลี่ยนพฤติกรรมการเรียนของฉันเพื่ออนาคต	( )	( )	( )	( )

ที่ดีขึ้น				
While I am learning, I am thinking about how much I enjoy it / เวลาที่ฉันเรียนหนังสืออยู่ บางทีฉันก็รู้สึกว่าฉันสนุกกับการเรียนมากเพียงใด	( )	( )	( )	( )
I am interested in a number of academic topics / ฉันมีความสนใจในหลากหลายวิชา	( )	( )	( )	( )

10.) If you are interested in receiving free access to the next version of REACH, please leave your email here. We will notify you as soon as the new version is available!

11.) How much do you agree with the following statements? / ฉันเห็นด้วยกับข้อความเหล่านี้มากน้อยเพียงใด (โปรดตอบตามความรู้สึกจริงของตัวเอง)

	Disagree / ไม่เห็นด้วย	Somewhat Agree/ ค่อนข้างเห็นด้วย	Agree / เห็นด้วย	Strongly Agree / เห็นด้วยอย่างยิ่ง
I will focus on the lessons in classes / ฉันจะพยายามตั้งใจเรียนในห้องเรียนให้มากขึ้น	( )	( )	( )	( )
I will try to finish my homework / ฉันจะพยายามทำการบ้านให้เสร็จอยู่เสมอ	( )	( )	( )	( )
I will raise up my hand to answer questions in the classroom more often / ฉันจะยกมือตอบคำถามเวลาที่อาจารย์ถามให้บ่อยขึ้น	( )	( )	( )	( )
When I have learning difficulty, I will keep trying different learning strategies until I overcome it/ เวลาฉันไม่เข้าใจในสิ่งที่เรียน ฉันจะพยายามค้นคว้าจนกว่าฉันจะเข้าใจด้วยตัวเอง	( )	( )	( )	( )
I will consult friends whenever I have learning difficulties / ฉันจะพยายามปรึกษาเพื่อนทุกครั้งที่ฉันรู้สึกว่าบทเรียนนั้นยาก	( )	( )	( )	( )
I will consult teachers whenever I have learning difficulties / ฉันจะพยายามปรึกษาอาจารย์ทุกครั้งที่ฉันรู้สึกว่าบทเรียนนั้นยาก	( )	( )	( )	( )
I will carefully recheck my homework to ensure accuracy / ฉันจะพยายามตรวจสอบการบ้านอย่างละเอียดเพื่อความถูกต้อง	( )	( )	( )	( )
I will try to study harder when I get a bad test score / ฉันจะพยายามขยันหาความรู้เพิ่มเติมเวลาที่ฉันได้คะแนนไม่ดี	( )	( )	( )	( )
I will try to prepare myself for all exams / ฉันจะพยายามเตรียมความพร้อมกับการสอบทุกครั้ง	( )	( )	( )	( )
I will consistently review the learning materials	( )	( )	( )	( )

outside the classroom / ฉันจะพยายามทบทวน "บทเรียน" เพิ่มเติมอย่างสม่ำเสมอนอกห้องเรียน				
I will systematically set time for reviewing learning materials / ฉันจะพยายามกำหนดเวลาอ่านหนังสือไว้อย่างเป็นระบบ	( )	( )	( )	( )
I will regularly surf the Internet to expand my academic knowledge base / ฉันจะพยายามค้นหาข้อมูลทางอินเตอร์เนทเพื่อเพิ่มฐานความรู้ของฉันเป็นประจำ	( )	( )	( )	( )
I will try reading supplementary books to enrich my understanding of class materials / ฉันจะพยายามอ่าน "หนังสือนอกห้องเรียน" ให้เยอะขึ้นเพื่อเพิ่มความเข้าใจกับสิ่งที่ฉันเรียนในห้อง	( )	( )	( )	( )
I will seek for more activities inside and outside schools to help me learn / ฉันจะพยายามเข้าร่วมกิจกรรมต่างๆที่จะช่วยสร้างเสริมประสบการณ์การเรียนรู้ของฉัน	( )	( )	( )	( )
I will systematically plan my study myself / ฉันจะพยายามวางแผนการเรียนให้เป็นระบบด้วยตัวฉันเอง	( )	( )	( )	( )
I will ask more assignments in group / ฉันจะพยายามขออาจารย์ที่จะทำงานเป็นกลุ่มมากขึ้น	( )	( )	( )	( )
I will cultivate the social relationships in academic work / หลังจากนี้ไป ฉันจะพยายามสร้างมิตรภาพในการทำงานกลุ่มที่โรงเรียน	( )	( )	( )	( )
I will pay more interest in a number of academic topics / ฉันจะพยายามสนใจเรียนในแทบทุกรายวิชา	( )	( )	( )	( )
I will think about my values when I have conflicts about time to be spent on achieving / ฉันจะพยายามเลือกทำในสิ่งที่สำคัญต่อตัวฉันที่สุด เวลาที่ฉันคิดอยากทำหลายๆอย่างพร้อมกัน	( )	( )	( )	( )
I wil enjoy intellectual challenges / ฉันจะพยายามลองแก้โจทย์ปัญหาที่ยากและท้าทายความสามารถให้บ่อยขึ้น	( )	( )	( )	( )
I will pay more interest in solving a problem set with which others have difficulties / ฉันจะพยายามแก้โจทย์ปัญหาที่เพื่อนๆคนอื่นทำไม่ได้	( )	( )	( )	( )
I will set myself realistic but challenging goals / ฉันจะตั้งเป้าหมายในการเรียนของฉันไว้สูงและสามารถทำได้	( )	( )	( )	( )

Appendix B2: Online Questionnaire Questions for Validating Defined Hypothesis (After Students Use Prototype)

1.) Your school name ? / ชื่อโรงเรียน

( ) สถาบันกวดวิชา BTS
( ) กรุงเทพคริสเตียนวิทยาลัย
( ) ไชยฉิมพลีวิทยาคม
( ) ดอนเมืองทหารอากาศบำรุง
( ) ทวีธาภิเศก 2
( ) ทีปังกรวิทยาพัฒน์(ทวีวัฒนา)ในพระราชูถัมภ์ฯ
( ) ทีปังกรวิทยาพัฒน์(วัดน้อยใน)ในพระราชูปถัมภ์ฯ
( ) นวมินทราชินูทิศ เบญจมราชาลัย
( ) นวมินทราชินูทิศ สตรีวิทยา พุทธมณฑล
( ) นวลนรดิศวิทยาคม รัชมังคลาภิเษก
( ) บางปะกอกวิทยาคม
( ) ปัญญาวรคุณ
( ) ประภามนตรี 2
( ) พญาไท
( ) พิทยาลงกรณ์พิทยาคม
( ) พิบูลประชาสรรค์
( ) พุทธจักรวิทยา
( ) มหรรณพาราม
( ) มัธยมวัดนายโรง
( ) โยธินบูรณะ
( ) ราชดำริ
( ) ราชวินิต
( ) วัดบวรมงคล
( ) วัดประดู่ในทรงธรรม
( ) วัดปากน้ำวิทยาคม
( ) วัดรางบัว
( ) วัดราชบพิธ
( ) วัดราชโอรส
( ) วัดโสมนัส
( ) ศึกษานารี
( ) สวนกุหลาบวิทยาลัย
( ) สารวิทยา
( ) สิริรัตนาธร
( ) อนุบาลสามเสนฯ
( ) อัสสัมชัญธนบุรี
( ) อำนวยศิลป์
( ) อื่น ๆ / Other

2.) Your student ID (Use National ID number if inapplicable)? / รหัสประจำตัวนักเรียนของโรงเรียน (ถ้าไม่มีให้ใช้เลขประจำตัวประชาชน)?

3.) How much do you agree with the following statements? / ฉันเห็นด้วยกับข้อความเหล่านี้มากน้อยเพียงใด (โปรดตอบตามความรู้สึกจริงของตัวเอง)

	Disagree / ไม่เห็นด้วย	Somewhat Agree/ ค่อนข้างเห็นด้วย	Agree / เห็นด้วย	Strongly Agree / เห็นด้วยอย่างยิ่ง
From now on, I will focus on the lessons in classes / หลังจากนี้ไป ฉันจะตั้งใจเรียนในห้องเรียนให้มากขึ้น	( )	( )	( )	( )
From now on, I will try to finish my homework / หลังจากนี้ไป ฉันจะพยายามทำการบ้านให้เสร็จอยู่เสมอ	( )	( )	( )	( )
From now on, I will raise up my hand to answer questions in the classroom more often / หลังจากนี้ไป ฉันจะยกมือตอบคำถามเวลาที่อาจารย์ถามให้บ่อยขึ้น	( )	( )	( )	( )
From now on, when I have learning difficulty, I will keep trying different learning strategies until I overcome it/ หลังจากนี้ไป เวลาฉันไม่เข้าใจในสิ่งที่เรียน ฉันจะพยายามค้นคว้าจนกว่าฉันจะเข้าใจด้วยตัวเอง	( )	( )	( )	( )
From now on, I will consult friends whenever I have learning difficulties / หลังจากนี้ไป ฉันจะปรึกษาเพื่อนทุกครั้งที่ฉันรู้สึกว่าบทเรียนนั้นยาก	( )	( )	( )	( )
From now on, I will consult teachers whenever I have learning difficulties / หลังจากนี้ไป ฉันจะปรึกษาอาจารย์ทุกครั้งที่ฉันรู้สึกว่าบทเรียนนั้นยาก	( )	( )	( )	( )
From now on, I will carefully recheck my homework to ensure accuracy / หลังจากนี้ไป ฉันจะตรวจสอบการบ้านอย่างละเอียดเพื่อความถูกต้อง	( )	( )	( )	( )
From now on, I will study harder when I get a bad test score / หลังจากนี้ไป ฉันจะขยันหาความรู้เพิ่มเติมเวลาที่ฉันได้คะแนนไม่ดี	( )	( )	( )	( )
From now on, I will prepare myself for all exams / หลังจากนี้ไป ฉันจะเตรียมความพร้อมกับการสอบทุกครั้ง	( )	( )	( )	( )
From now on, I will consistently review the learning materials outside the classroom / หลังจากนี้ไป ฉันจะทบทวน "บทเรียน" เพิ่มเติมอย่างสม่ำเสมอนอกห้องเรียน	( )	( )	( )	( )
From now on, I will systematically set time for reviewing learning materials / หลังจากนี้ไป ฉันจะกำหนดเวลาอ่านหนังสือไว้อย่างเป็นระบบ	( )	( )	( )	( )
From now on, I will regularly surf the Internet to expand my academic knowledge base / หลังจากนี้ไป ฉันจะค้นหาข้อมูลทางอินเตอร์เนทเพื่อเพิ่มฐานความรู้ของฉันเป็นประจำ	( )	( )	( )	( )
From now on, I will read supplementary books to enrich my	( )	( )	( )	( )

understanding of class materials / หลังจากนี้ไป ฉันจะอ่าน "หนังสือนอกห้องเรียน" ให้เยอะขึ้นเพื่อเพิ่มความเข้าใจกับสิ่งที่ฉันเรียนในห้อง				
From now on, I will seek for activities inside and outside schools to help me learn / หลังจากนี้ไป ฉันจะเข้าร่วมกิจกรรมต่างๆที่จะช่วยสร้างเสริมประสบการณ์การเรียนรู้ของฉัน	( )	( )	( )	( )
From now on, I will systematically plan my study myself / หลังจากนี้ไป ฉันจะวางแผนการเรียนให้เป็นระบบด้วยตัวฉันเอง	( )	( )	( )	( )
From now on, I will ask more assignments in group / หลังจากนี้ไป ฉันจะพยายามขออาจารย์ที่จะทำงานเป็นกลุ่ม	( )	( )	( )	( )
From now on, I will cultivate the social relationships in academic work / หลังจากนี้ไป ฉันจะพยายามสร้างมิตรภาพในการทำงานกลุ่มที่โรงเรียน	( )	( )	( )	( )
From now on, I will pay more interest in a number of academic topics / หลังจากนี้ไป ฉันจะพยายามสนใจเรียนในแทบทุกรายวิชา	( )	( )	( )	( )
From now on, I will think about my values when I have conflicts about time to be spent on achieving / หลังจากนี้ไป ฉันจะเลือกทำในสิ่งที่สำคัญต่อตัวฉันที่สุด เวลาที่ฉันคิดอยากทำหลายๆอย่างพร้อมกัน	( )	( )	( )	( )
From now on, I wil enjoy intellectual challenges / หลังจากนี้ไป ฉันจะลองแก้โจทย์ปัญหาที่ยากและท้าทายความสามารถให้บ่อยขึ้น	( )	( )	( )	( )
From now on, I will pay more interest in solving a problem set with which others have difficulties / หลังจากนี้ไป ฉันจะพยายามแก้โจทย์ปัญหาที่เพื่อนๆคนอื่นทำไม่ได้	( )	( )	( )	( )
From now on, I will set myself realistic but challenging goals / หลังจากนี้ไป ฉันจะตั้งเป้าหมายในการเรียนของฉันไว้สูงและสามารถทำได้	( )	( )	( )	( )

4.) How much do you agree with the following statements after playing REACH? /
ฉันเห็นด้วยกับข้อความเหล่านี้มากน้อยเพียงใดหลังจากที่ได้ลองเล่นโปรแกรม REACH
(โปรดตอบตามความรู้สึกจริงของตัวเอง)

	Disagree / ไม่เห็นด้วย	Somewhat Agree/ ค่อนข้างเห็นด้วย	Agree / เห็นด้วย	Strongly Agree / เห็นด้วยอย่างยิ่ง
I still feel that I study hard / ฉันยังรู้สึกว่าฉันเรียนหนังสือหนัก	( )	( )	( )	( )
I still want to skip some boring classes although I know it helps me develop skills / ฉันยังอยากโดดเรียนวิชาที่ฉันว่าน่าเบื่อแม้ว่าสิ่งที่เรียนในวิชา	( )	( )	( )	( )

นั้นจะช่วยพัฒนาความสามารถของฉัน				
Learning will not hold my attention at all / การเรียนหนังสือจะยังทำให้ฉันไม่มีความสนใจเหมือนเดิม	( )	( )	( )	( )
I still feel that I love learning / ฉันยังรู้สึกรักการเรียนหนังสือ	( )	( )	( )	( )
I now see the value of the knowledge concepts / ตอนนี้ฉันเห็นคุณค่าขององค์ความรู้ต่างๆ	( )	( )	( )	( )
I now understand how the knowledge concepts develop my skills / ตอนนี้ฉันเข้าใจว่าองค์ความรู้สามารถพัฒนาให้ฉันมีทักษะต่างๆได้อย่างไร	( )	( )	( )	( )
I now understand why I need to learn / ตอนนี้ฉันเข้าใจดีว่าเหตุใดฉันจำเป็นต้องเรียนรู้	( )	( )	( )	( )
Learning will be more fun to do / หลังจากนี้ การเรียนหนังสือจะเป็นสิ่งที่สนุกสำหรับฉัน	( )	( )	( )	( )
I now see the value of education / ตอนนี้ฉันเห็นคุณค่าของการศึกษา	( )	( )	( )	( )
I now believe that I can do everything If I intend to do / ตอนนี้ฉันเชื่อว่าฉันทำได้ทุกอย่างถ้าฉันตั้งใจ	( )	( )	( )	( )
I will now describe learning as very interesting / ตอนนี้ฉันพูดได้ว่าการเรียนเป็นสิ่งที่น่าสนใจ	( )	( )	( )	( )
If I get a scholarship, I will to pursue a Phd degree although it will takes 6 years to complete / ถ้าฉันได้ทุน ตอนนี้ฉันอยากจะเรียนต่อให้ถึงปริญญาเอกแม้ว่าจะต้องใช้เวลาถึง 6 ปี	( )	( )	( )	( )
I will enjoy learning very much / ฉันจะสนุกกับการเรียนหนังสือให้มากขึ้นกว่าเดิม	( )	( )	( )	( )
I will change my learning behavior for better future / ตอนนี้ฉันจะเปลี่ยนพฤติกรรมการเรียนของฉันเพื่ออนาคตที่ดีขึ้น	( )	( )	( )	( )
While I am learning, I will be thinking about how much I enjoy it / เวลาที่ฉันเรียนหนังสืออยู่ ฉันจะลองคิดดูว่าฉันสนุกกับการเรียนมากเพียงใด	( )	( )	( )	( )
I will be interested in a number of academic topics / ฉันจะสนใจในหลากหลายวิชามากยิ่งขึ้น	( )	( )	( )	( )

5.) If I could improve the tool, I would ... / หากฉันจะปรับปรุงโปรแกรมนี้ ฉันจะ ...

6.) Please leave constructive comments to the developer if any / กรุณาให้ข้อคิดเห็นแก่ผู้พัฒนาระบบเพื่อใช้ในการปรับปรุงระบบในอนาคต

Appendix C1: Questionnaire Items used in a case study no.2 conducted by University of Berkeley Bear Center

High School: _____

City of high school _____

Year in school (grade): _____

Cum High School GPA: _____

Directions: Pick the best answer that describes you. *(Academic Behavior)*

1. I am on time for school
   (A) Never.
   (B) Sometimes.
   (C) Most of the time.
   (D) Always.
2. I turn in my homework
   (A) Never.
   (B) Sometimes.
   (C) Most of the time.
   (D) Always.
3. I finish my homework
   (A) Never.
   (B) Sometimes.
   (C) Most of the time.
   (D) Always.
4. When I have an examination, I study
   (A) Never.
   (B) Sometimes.
   (C) Most of the time.
   (D) Always.
5. I participate in class discussion
   (A) Never.
   (B) Sometimes.
   (C) Most of the time.
   (D) Always.
6. I study for an examination
   (A) Never.
   (B) The night before.
   (C) A couple of days before.
   (D) A week or more before.
7. I finish class assignments
   (A) Never.
   (B) Sometimes.
   (C) Most of the time.
   (D) Always.
8. I turn in my class assignments on time
   (A) Never.
   (B) Sometimes.
   (C) Most of the time.
   (D) Always.
9. I turn in homework on time
   (A) Never.
   (B) Sometimes.

(C) Most of the time.

(D) Always.

10. I pay attention during class

(A) Never.

(B) Sometimes.

(C) Most of the time.

(D) Always.

11. When given a group assignment, I participate with my group

(A) Never.

(B) Most of the time.

(C) Sometimes.

(D) Always.

12. When I do not understand something, I ask the instructor

(A) Never.

(B) Most of the time.

(C) Sometimes.

(D) Always.

13. I take notes in class

(A) Never.

(B) Most of the time.

(C) Sometimes.

(D) Always.

14. I complete my reading assignments

(A) Never.

(B) Most of the time.

(C) Sometimes.

(D) Always.

15. I check my homework

(A) Never.

(B) Most of the time.

(C) Sometimes.

(D) Always.

(Behaviors/Actions Towards College)

16. I have taken the SAT

(A) No.

(B) Yes.

17. I am planning to take the SAT

(A) Never and do not plan on taking it.

(B) Never, but I am thinking of taking it.

(C) Never, but I am signed-up to take it.

(D) I have taken the SAT.

18. I have taken the SAT

(A) Never.

(B) One time.

(C) Two times.

(D) Three or more times.

19. I plan to take the SAT a total of

(A) 0 times.

(B) 1 time.

(C) 2 times.

(D) 3 or more times.

20. I have taken the ACT

(A) No.

(B) Yes.

21. I am planning to take the ACT

(A) Never and do not plan on taking it.

(B) Never, but I am thinking of taking it.

(C) Never, but I am signed-up to take it.

(D) I have taken the ACT.

22. I have taken the ACT

(A) Never.

(B) One time.

(C) Two times.

(D) Three or more times.

23. I plan to take the ACT a total of

(A) 0 times.

(B) 1 time.

(C) 2 times.

(D) 3 or more times.

24. I have taken a honors class(es) in school

(A) No.

(B) Yes.

25. I have taken a total number of honors classes

(A) 0 times.

(B) 1 time.

(C) 2 times.

(D) 3 or more times.

26. If given the opportunity, in the future I would

(A) Never take an honors course.

(B) Might take an honors course.

(C) Probably take an honors course.

(D) Most certainly take an honors course.

27. I would take an honors class after school if it were not offered during the day.

(A) No.
(B) Yes.

28. I would take an honors class at another school (after school) if it were not offered at my school.

(A) No.
(B) Yes.

29. I have taken an Advance Placement course(s) in school

(A) No.

(B) Yes.

30. What is the total number of AP classes that you have taken?

(A) 0 times.

(B) 1 time.

(C) 2 times.

(D) 3 or more times.

31. If given the opportunity, in the future I would

(A) Never take an Advance Placement course.

(B) Might take an Advance Placement course.

(C) Probably take an Advance Placement course.

(D) Most certainly take an Advance Placement course.

32. I would take an advance placement course after school if it were not offered during the day

(A) No.
(B) Yes.

33. I would take an advance placement course at another school (after school) if it were not offered at my school

(A) No.
(B) Yes.

34. I have taken a city college course

(A) No.

(B) Yes.

35. If given the opportunity, I would take a city college course after school

(A) No.

(B) Yes.

36. If given the opportunity, I would take one city college course two days a week after school from 3:30 pm – 5:50 pm

(A) No.

(B) Yes.

37. If given the opportunity, I would take one city college course four days a week after school from 3:30 pm – 5:50 pm

(A) No.

(B) Yes.

38. If given the opportunity, I would take one city college course on Saturday from 9:00 am – 12:00 noon

(A) No.

(B) Yes.

39. If given the opportunity, I would take one city college course on Saturday from 9:00 am – 3:00 pm

(A) No.

(B) Yes.

40. If given the opportunity, I would take one city college course on Saturday from 9:00 am – 6:00 pm

(A) No.

(B) Yes.

(Attitudes Towards College)

41. If you were given a full four-year scholarship would you go to college?

(A) No.
(B) Yes.

42. If you were given a two-year scholarship, and you had to pay (with loans) for the last two years would you go to college?

(A) No.
(B) Yes.

43. If you were given a one-year scholarship, and you had to pay (with loans) for the last three years would you go to college?

(A) No.
(B) Yes.

44. If you were not given a scholarship and you had to pay (with loans) for four years of college would you go to college?

(A) No.
(B) Yes.

45. If you were given the opportunity to attend college and did not have to work, would you go?

(A) No.
(B) Yes.

46. If you were given the opportunity to attend college but had to work part-time, would you go?

(A) No.
(B) Yes.

47. If you were given the opportunity to attend college but had to work full-time, would you go?

(A) No.
(B) Yes.

48. If you were given admission to the college of your choice, would you go?

(A) No.
(B) Yes.

49. If you were denied from the college of your choice, but admitted into your second college of your choice, would you go?

(A) No.
(B) Yes.

50. If you only were accepted into your last choice of college, would you go?

(A) No.
(B) Yes.

51. If you were not accepted into any college would you attend a junior college and transfer after two years?

(A) No.
(B) Yes.

52. Do you think college is important?

(A) No.
(B) Yes.

53. Do you think a college degree is important?

(A) No.
(B) Yes.

54. Would you go to college if it provided you with an extremely pleasant lifestyle when you graduated, and you had the job of your choice?

(A) No.
(B) Yes.

55. Would you go to college if it provided you a comfortable lifestyle when you graduated, and you had the job of your choice?

(A) No.
(B) Yes.

56. Would you go to college if it provided you an uncomfortable lifestyle when you graduate, but you had the job of your choice?

(A) No.
(B) Yes.

Appendix C2: Questionnaire Items of a New Scale to Measure Motivation to Achieve Academically

Please rate the 48 items according to the following response format and place a number corresponding to **What I aim for** and **What I actually do** on the appropriate line opposite each statement:

In all or nearly all my subjects	**put 3**
In most, though not all, my subjects	**put 2**
In some, though not most, of my subjects	**put 1**
In none or only one of my subjects	**put 0**

Example: If **you aim to set high standards** in academic work for all your subjects, put 3, and if **this only happens** in some subjects, put 1.
Item 1. I set myself high standards in academic work. 3 1

Item no.	Item wording	What I aim for	What I actually do
Subscale:	**Striving for Excellence (11 stem-items fit the model)**		
Standards			
1/2	Do my best to reach the academic standards that I set for myself	−0.97	−0.55
3/4	Evaluate my performance against the academic standards that I set myself	+0.14	+0.45
	Set myself the highest standards in academic work which I believe I can achieve.	Did not fit the model	
Goals			
5/6	Try different strategies to achieve my academic goals when I have difficulties.	−0.07	+0.69
7/8	Set myself realistic but challenging academic goals.	−0.28	−0.11
	Set the highest academic goals which I can achieve.	Did not fit the model	
	When I have difficulties in reaching my goals, I make a renewed effort to ensure I achieve my goals.	Did not fit the model	
Tasks			
9/10	Seek some average academic tasks in which I think I can succeed.	+0.38	+0.52
11/12	Seek some difficult academic tasks in which I believe I can succeed.	+0.45	+1.26
13/14	Seek some difficult academic tasks which I might be able to do.	+0.67	+1.35
	Seek some easy academic tasks in which I am strongly likely to succeed.	Did not fit the model	
	Seek some easy academic tasks which I might be able to do.	Did not fit the model	
Effort			
15/16	Make strong demands on myself to achieve in academic work.	−1.14	+0.30
17/18	When I am given an academic task or assignment, I make a strong effort to find the right answers.	−1.05	−0.66
19/20	Write and re-write my academic assignments in order to achieve.	−0.09	+0.75
	Prepare myself to achieve as high as I can in my academic assignments.	Did not fit the model	
	Make a strong effort to achieve as high as I can in academic work.	Did not fit the model	

Item no.	Item wording	What I aim for	What I actually do
Values			
21/22	When I have conflicts about time to be spent on achieving, I re-think my values (social, parental, dates versus achievement).	−0.10	+0.71
	Value achievement in academic work.	Did not fit the model	
Ability			
	Have confidence in my academic ability to achieve the best that is possible with my ability.	Did not fit the model	
	Have positive feedback from my teachers on my ability in academic work.	Did not fit the model	
	Have positive feedback from at least one peer friend on my ability in academic work.	Did not fit the model	
	Have positive feedback from at least one parent (or guardian) on my ability in academic work.	Did not fit the model	
Subscale:	**Desire to Learn (9 stem-items fit the model)**		
Interest			
23/24	Show interest in a number of academic topics.	−0.94	−0.38
25/26	Read widely on a number of academic topics.	+0.08	+1.08
27/28	Think about solving problems, with which others have difficulty, because I'm interested.	+0.12	+0.85
	Display curiosity about the world and 'how it works'.	Did not fit the model	
	Behave conscientiously in my academic work.	Did not fit the model	
Learning from others			
29/30	Participate in class discussions to improve my understanding in academic matters.	−0.71	+0.61
31/32	Ask questions of others to improve my understanding in academic matters.	−0.69	+0.36
33/34	Learn from others with more knowledge than I have.	−0.49	+0.00
35/36	Aim to learn from an expert in at least one academic area.	−0.21	+0.36
	Try to pay attention to my teachers in order to learn as much as I can.	Did not fit the model	
Responsibility for learning			
37/38	Take personal responsibility for my academic learning.	−1.68	−0.35
39/40	Plan to seek out information when necessary and take steps to master it.	−1.47	−0.33
Subscale:	**Personal Incentives (4 stem-items fit the model)**		
Extrinsic Rewards			
	Try to achieve academically because I like the rewards it brings to me.	Did not fit the model	
	Try to achieve academically because I like the status it brings to me.	Did not fit the model	
	Try to achieve academically because I like the competition with others that it brings.	Did not fit the model	
Intrinsic Rewards			
41/42	Like the interaction with peers in solving problems in academic work.	−0.18	+0.35
43/44	Try to achieve academically because I like the challenges it brings.	−0.11	+0.63
45/46	Like the intellectual challenge of academic work.	+0.08	+0.64
	Like the curiosity of academic work.	Did not fit the model	

Item no.	Item wording	What I aim for	What I actually do
Social Rewards			
47/48	Like the social relationships involved in academic work.	−0.34	+0.08
	Have fun with others while involved in academic work.	Did not fit the model	
	Bring honor to my family by succeeding in academic work.	Did not fit the model	

Notes

1. Item 'difficulties' are in logits (log odds of answering positively)
2. The lower the item 'difficulty', the 'easier' the item
3. The higher the item 'difficulty', the 'harder' the item
4. Items at the 'easiest' end of the scale are answered positively by almost all the students. Students need a high motivation to answer the 'hardest' items positively.
5. The *What I aim for* items are 'easier' than the *What I actually do* items.
6. The standard errors vary from about 0.09 to 0.20 (see Appendix 2)