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Research Laboratory-Based Learning (LBL) Methodology in Instilling Multi Skills and Ethical Work Habits for Engineering Students in Japan

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Abstract: This study introduces research Laboratory-Based Learning (LBL) as a practical learning methodology for engineering students at Japanese universities. LBL methodology is mainly based on Vygotsky's social constructivism learning theory. In LBL methodology, students are encouraged to experience free exploration during learning process while at the same time the social interaction and apprenticeship culture embedded in this methodology are able to instill multi skills and ethical work habits among the students. There are nine elements that characterized LBL methodology: professor leadership, structured organization, enclosed physical environment, group research, mentoring and apprenticeship, engagement in research tasks and activities, student-centered approach, holistic approach and cohort system. Learning by LBL methodology is akin to working in a well-established corporate factory in terms of commitment delivered and the professional working style practiced. Such learning experience instills positive attributes in graduates and designs employable graduates tailor-made to fit well in the job markets. This study therefore, attempts to suggest LBL method to be implemented for undergraduate (final year students) and postgraduate program or any research group in university, in the hope that the teaching and learning experience, particularly in engineering and technology program, can be enhanced and be made more meaningful.

Key words: Research laboratory-based learning, social interaction, apprenticeship, multi skills, ethical work habits

INTRODUCTION

Constructivism learning theories: Learning theories can be categorized into three main paradigms; behaviorism, cognitivism and constructivism. Constructivism learning theories emphasize that students construct new knowledge through their own experience and active involvement in the learning process. Based on these theories, people actively construct or create their own subjective representation of objective reality. Among the originators and important contributors of these theories are Dewey, Bruner, Piaget and Vygotsky.

John Dewey, an American education philosopher and one of the most influential reformers in progressive education insisted that the best way of learning is through experience and activity, rather than by rote learning. This method is also called "learning by doing" or active learning.

The idea of constructivism is often associated to Piaget's Theory of Cognitive Development. According to Piaget, students construct new knowledge from their experience through the processes of accommodation and assimilation. Accommodation is the process of restructuring of mental structure or "scheme" to the outside world so as to correspond with a new experience. If the new information is very different from the existing mental structure, it does not make any sense to incorporate them into the structure. The new information is either rejected or it is assimilated or transformed so that it will fit into the structure (Piaget, 1950).

Constructivist learning theory has been supported by many educationists but there are also many of them who criticized the theory, particularly in terms of its approach and methodology (Sweller, 1988). The central issue is that when students are given too much freedom, they are likely fail to find "the things that must be learned" (Mayer, 2004).

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Most of the critics pointed out against constructivism learning methods such as inquiry-discovery and problem-based learning are due to insufficient emphasis of these methods on structured guided learning that can encourage students to experience free exploration while attaining the expected learning objectives (Kirshner *et al*., 2006).

Vygotsky's constructivism theory: This learning theory asserts that individual learning occurs due to the social interaction among members within a group. Vygotsky emphasized the importance of social interaction in learning. In the context of constructivism, Piaget's view of knowledge construction is proactive while Vygotsky's view is collective; social interaction leads to increased knowledge.

In his Proximal Development Theory, Vygotsky stated that the achievements of students in solving problems are better under adult guidance or in collaboration with peers rather than through their own efforts alone (Vygotsky, 1978).

Apprenticeship in education: Apprenticeship is a social learning method with a long history of developing novices to become experts in diverse fields from midwifery, construction, trade industries to law. The foundation of apprenticeship learning methodology is centered on the concept of more experienced people assisting less experienced ones, providing structure and example to support the attainment of goals.

It is worthwhile to mention that the concept of learning from experts through social interactions should not be limited to vocational and trade-based training only. Apprenticeship as a method of teaching and learning is just as relevant within the cognitive and metacognitive domain as it is in the psychomotor domain. This method is called cognitive apprenticeship (Lave and Wenger, 1991).

In constructivism learning process, social support by peers or experts who are more knowledgeable and experienced is called scaffolding. It aims to establish a dynamic support for students to complete tasks beyond of Zone of Proximal Development (ZPD) and then gradually reduce this support until it is no longer needed or relied on (Brown *et al*., 1989).

The ZPD concept which was put forth by Vygotsky, suggests that learning activities should provide adequate challenges to the student based on his or her current knowledge state but at the same time not too challenging as to be unattainable. The ZPD is a dynamic region that is beyond the student's present level of ability as learners gain new skills and knowledge their ZPD moves with their development.

Research laboratory in Japan: Engineering students in Japanese universities are required to complete four years of study to be awarded Bachelor's degree in Engineering. During the 1st 3 years, the students are required to attend classes comprised of general education, health education, basic sciences as well as specialized engineering subjects which are the core components of their study.

In the final year of the undergraduate program, the fourth year, every student is required to select a research laboratory, depending on his or her area of interest. This is to enable research work be carried out for thesis writing as required in the curriculum to fulfil graduation requirements. When the student joins a research laboratory he or she becomes a full-time member of the laboratory.

In a Japanese university, the research laboratory is where all research activities take place. It has its own specialization and research themes. For example, in the Faculty of Mechanical Engineering there are several laboratories that are assigned specialized topics such as material strength, engines, fluid dynamics, industrial designs and mechanical simulation. Each research laboratory is led by a professor and assisted by a few associate professors. This system or kouzasei which means chair system is widely practiced in Japanese universities.

Accommodating postgraduates and undergraduates, research laboratories are practically identified by the names of the professors who head these laboratories. For example there would be laboratories named as Yasuda Kenkyushitsu, Ishikawa Kenkyushitsu, Tanaka Kenkyushitsu and others. This system is called laboratory-based system or kenkyushitsei.

The group members are given several benefits such as workstations or a room in which group members can stay in and they are given full access, 24/7 to the laboratory assigned to them.

MATERIALS AND METHODS

This study attempts to introduce Laboratory-Based Learning (LBL) methodology which is widely practiced in research laboratories in Japanese universities on the basis of theoretical provisions made by several social constructivism philosophers including those works pioneered by Dewey (1987), Piaget and Vygotsky which then blended with some modern interpretation through the works of Lave, Brown, Mayer, Kirshner, Ernest, Duffy, Savery, Sweller and many others.

The practical implementation of these theories in LBL methodology as presented in this study was personally

observed and experienced by the authors (one of whom graduated from a Japanese university while another was involved in research collaboration with another Japanese university).

RESULTS AND DISCUSSION

The term Laboratory-Based Learning (LBL) used in this paper refers to a formalized and structured relationship of a professor and/or senior students as mentors to more junior students that engaged in highly advanced research activities in a research laboratory. LBL is mainly based on Vygotsky's social constructivism learning theory which is supported by two principal pillars; social interaction system and apprenticeship culture.

The social interaction system and apprenticeship culture then can be characterized further by nine key elements:

- Professor leadership
- Structured organization
- Enclosed physical environment
- Group works
- Mentoring and apprenticeship
- Engagement in research tasks and activities
- Student-centered approach
- Holistic approach
- Cohort system

All of these elements build the structure of organized learning atmosphere that accelerates active participation of students through engagement in research tasks and activities under the foundation of effective social interaction and deeply rooted apprenticeship culture. All the nine criteria are interdependent therefore, neglecting one of the elements would reduce the achievement of the learning outcomes.

The outcomes of LBL methodology are tangible and intangible, ranging from academic success for example, participation in academic conferences and publishing articles in reputable journals, to socio-emotional benefits such as supportive relationship among laboratory members and personal growth; particularly in the mastery of knowledge and skills and in instilling good ethical work habits.

Professor leadership: In any field, whether in politics, education, economy, military and even in the entertainment world there is a natural need for a leader that can guide and drive the advancement of their respective fields. Similarly, in the community of a research laboratory, it should be headed by a leader that is a professor who would be the source of expertise and inspiration for among all laboratory members.

The presence of a professor as the key More Knowledgeable Other (MKO) who is actually working in the laboratory allows the students as well as the associate professors to rely on as they work through ZPD (Tharp and Gallimore, 1988).

A professor's status in his or her research laboratory is similar to the masters (sensei) of Japanese martial arts like aikido, judo and kendo who have their own training arena. A master leads the arena and trains hundreds of students. During this training process, the knowledge and skills of the master are systematically passed down to younger generations. This traditional mechanism of knowledge transfer is still relevant in modern society.

Among the important aspects aimed by the professor is how he or she can share and transfer expertise to subordinates; the associate professors and students. This unique apprenticeship system is traditionally rooted in Japanese culture as the approach that has been practiced in Japanese handcrafts and carpentry (Yokota *et al*., 2014) and also in martial arts as mentioned before.

Structured organization: In Japan, research laboratory is typically headed by a professor who is assisted by two or three associate professors. Each associate professor then leads a small research team which has specific research themes. There are three or more PhD and Masters students and two or three final year students of undergraduate program in each research team.

Within this small organization, social interaction among members within the research team and with other research teams can be accelerated through oral discussions and practical activities undertaken in the laboratory environment. Moreover, all members; the professor associate professors and students are working in the laboratory almost all time. This highly efficient social interaction system would definitely accelerate the learning process.

There are socio-emotional gains embedded in the student behavior as well including increased confidence, pride and a sense of being connected to a supportive research community of the same research interests. Learning that occurs within a similar community fosters personal and emotional commitment and a sense of belonging and connections to a larger culture (Paradise and Rogoff, 2009).

It also validates view of some educationists that knowledge is a human product and it is built on social and

cultural foundation thus, knowledge should be developed through human social activities and interactions (Ernest, 1991).

In short, the structured research organization as incorporated in the research laboratory promotes smart partnerships, simplifying the learning process for all members of the laboratory.

Enclosed physical environment: This means that all members of the laboratory; students associate professors and the professor are working in the same laboratory almost all the time.

Through carefully designed work space and layout, all members in the laboratory can interact more directly and efficiently. This layout has many practical advantages particularly for new students to observe and emulate the research techniques and also work ethics from the senior members of laboratory especially when the professor and senior students are working just in front of them.

Teaching and learning through this apprenticeship approach acquires making practical activities visible to the students so they can observe and the practice them (Collins *et al*., 1989).

Besides, the enclosed physical environment of the laboratory can inculcate a high sense of belonging among members thus elevates their commitment to the research works.

This phenomenon is common in Japanese culture. Social interaction is maximized through the construction of enclosed physical barriers such as walls, partitions and rooms. Schools in Japan are usually surrounded by walls to enhance sense of belonging to the institutions and highlighting the idea that the identity of institution has higher priority over the individual (Rohlen and Tendre, 1999). In Japan, the layout of teacher's room is also designed in such a way to facilitate collaboration.

Group works: One of the most impressive characteristics of Japanese society is the concept of group. It is adheres to the idea that each person requires identity and membership of a group.

This can be proven by simple fact that in the Japanese language most of the social and cultural activities such as kouryuukai, taikai, hanamikai and many more end with "kai" which means groups, meetings and organizations.

Constructivism theories emphasize learning through close collaboration among students. Students with various academic backgrounds and levels shall cooperate in particular tasks and discussions in order to reach an appropriate understanding in a particular field (Duffy and Jonassen, 1992).

The laboratory is the center of the activities of its members whom can be defined as a group of people sharing very specific research objectives and work collectively in the laboratory to achieve those objectives.

To provide sense of ownership, each student in the laboratory receives different research topic from the other. However, most of the research activities are carried out in groups. For example, the task of reviewing literature is done as a group activity in which the entire group members are involved. It is termed in various ways, for example shorokukai, zasshikai, bunken zemi, etc.

It is the responsibility of each member of the research team to introduce the latest update of research findings on the topic similar to their research theme. This group discussion is conducted in weekly basis and consists of five to eight persons and in presence of the professor and associate professors.

Besides disseminating in-depth knowledge on a particular research topic, these activities provide opportunities for the students to enhance their proficiency and competency in reading, writing and communicative soft skills. The reviewing tasks also nurture skills such as gathering data and information, understanding technical reports and strengthening skill of digesting ideas and information from other people's work and then assimilating these work into another language from English to Japanese.

Such continuous exposure to latest research findings enables all members of the laboratory including the professor associate professors and students to obtain valuable input and utilize it while conducting their own research. Perhaps this is the secret of how Japan can instantly assimilate the latest knowledge and technology successfully.

Group activities also allow students to complement each other. This means, no student is left behind in the learning process. Excellent or more experienced students help poor students. In the Japanese education system, there is no clear polarity between outstanding and poor students (Rohlen and Tendre, 1999).

The group works that deeply internalized within the research group are able to harness powerful synergy among the members and it is visible through research and other activities carried out in the laboratory.

When research conducted is successful, credit is given to the research group and not any particular individual. This contributes towards a sense of belonging among the members of the group, regardless of whether he or she is the professor associate professors or students.

Mentoring and apprenticeship: Another unique characteristic of the Japanese society is mentoring, modeling and apprenticeship culture that has traditionally been practiced particularly in educational institutions and workplaces (Fukuda, 1988).

In this culture, each person is responsible to guide his or her subordinates and most importantly to ensure that knowledge and skills necessary for the sustainability of the organization are passed down to the next generation.

In the LBL methodology, all members of the laboratory have their own responsibility. For example, the professor is responsible for guiding the associate professors to attain more research outputs until they qualify for professorship. Similarly, the associate professors guide postgraduate students under their supervision. The postgraduate students meanwhile are required to "watch over" the undergraduate students.

New students in the laboratory adapt quickly to the laboratory environment and research tasks because the learning takes place under the guidance of someone more knowledgeable and skilled (Driver *et al*., 1994).

The new students then gradually scaffold the knowledge and experience obtained during this process into a more coherent and independent research tasks. This provides a foundational experience that would lead to more in-depth research endeavor in subsequent semesters, in which they then become mentors.

In addition this inter-generational and cross-cohort mentoring also provides mechanism of retaining the skill, expertise and culture that are unique to the laboratory to be ingrained and permanently "preserved" even the members of the laboratory change over the time. This kind of apprenticeship system is commonly adopted by Japanese companies to produce skilled and competent workers. Employees who are more senior and skilled are required to teach the job know-how to subordinates until it can be handed down from one generation to another (William, 1993).

Engagement in research tasks and activities: According to constructivism theories, students should be given more challenging tasks and activities meaningful to them to effectively build knowledge. After gaining experience of successfully completing a particular task, students gain confidence and motivation to challenge a more complex task (Vygosky, 1978). This would increase the motivation where previous success becomes a foundation for the students to build confidence (Brownstein, 2000).

Lave pioneered the concept of situated learning that is as it normally occurs, learning is embedded within activity, context and culture (Lave, 1988). Social interaction and collaboration are indispensable elements of situated learning? students become involved in a "community practice" which practice certain beliefs and behaviors to be acquired. The engagement in research tasks and activities is a situated learning that takes place in conducive laboratory environment.

Current education systems, particularly those adopted in universities, have been criticized for separating learning from practice, resulting in an education that ill-prepared for job performance (Enkenberg, 2001). In other words, these systems are criticized because they are lacking of situatedness and fail to engage learners in authentic practices with cultural tools and natural performance conditions.

The main task of the students in the laboratory is conducting research work (kenkyuu). Each student is given a different research topic but is interconnected to other students' topics in terms of research areas, facilities, tools, methods and references. This would open opportunities for students to interact and help each other. Furthermore, it simplifies the process of evaluation and monitoring.

It is globally well known that Japanese are obsessed with work (shigoto) and they have been nurtured, since childhood to have the right attitude towards work. The same thing happens in the research laboratory. While doing research, Japanese students do not waste time and perform the tasks with dedication and honor.

Indeed, students' life upon entering the research laboratory can turn out to be very hectic as they would be occupied with research tasks and activities. Working in the laboratory is like working in a typical Japanese company. They need to turn up at the laboratory before the professor arrives (about 8:30 a.m.) then continue to work until late night. They return home only to get a few hour sleep while some even sleep in the laboratory!

Student-centered approach: In the research laboratory, students manage almost all aspects of laboratory operations. It includes the management and handling of machines, materials and apparatus as well as the safety and environmental aspects within the laboratory area. The students also hold several social activities all-year round. These activities would not be possible without full cooperation and healthy social interaction among members of the laboratory.

All students are given responsibilities for ensuring that all research operations run properly. However, the senior students always ensure that operations are carried out correctly and safely.

Brief training on materials and equipment handling is normally provided by senior students and then junior students will work independently until they become experts and can take care of their own research works with minimal supervision. This allows the learning experience to be open and free at the level that allows them to explore, enjoy and interact (Savery and Duffy, 1995).

The students thoroughly master all the works required in conducting research. For example, for a student to conduct research in organic chemistry, he or she needs to do all the work including purchasing chemicals, performing glass works, installing equipment, conduct experiments, review literature, operating equipment such as NMR and GC and separating scheduled wastes by categories without depending on technicians.

Activities that seem "trivial" such as sweeping and cleaning the laboratory are also conducted as laboratory work routine. In actuality, students are already accustomed to this routine because they have been practicing it since kindergarten. In Japanese schools, students often clean classroom without being directly ordered by teacher. The real social impact of this practice is that students learn about responsibility and group harmony at the early stages of their life (White, 1987).

This comprehensive mastery learning process reflects how knowledge should be constructed. Knowledge should not be divided into many different parts, on the contrary, it should be explored in an integrated way.

Holistic approach: In traditional and modern Japanese society there is a learning approach called karada de oboeru which means learning inside-out that is, "learning by doing" using the four main intelligence of human nature; physical, mental, spiritual and social/emotional (Aludin, 2012). While doing research in laboratory, students have to use the entire body and soul and their potential, to perform all the tasks and activities provided. This learning experience allows for students to attain multiple skills and working ethics in the social structure of the research laboratory.

Besides concentrating on doing laboratory works, it is a tradition for students to organize a few 'kai' which means gathering or party, for them to spend some enjoyable times together.

The cycle of gathering starts with kangeikai at the beginning of the semester, hanamikai in spring, undokai during summer, kenkyushitsu ryoko in autumn, bounenkai in December and finally soubetsukai at the end of the second semester. These activities are organized all-year round seasonally by the students. Through these properly planned activities, students can have non-academic time together which would give them the opportunity to deepen their relationship.

Sports and games activities promote body-kinetics skills. They are not only excellent in academic and research field but in sports as well. Activities such as cherry blossom viewing (hanami) and tour promote the feel of pride and love to their own unique cultural heritage in their nation.

Even in these activities which provide enjoyment and time together, the concept of seniority is not overlooked. It is important for (especially new) students to build some form of mutual trust and understanding. This creates social skills of adapting in a new environment when they join companies as new employees.

After all these activities indirectly "teach" the students on how to manage stress. Stress is a common thing in life whether in research laboratory or workplace and it should not be managed alone.

This integrated approach can be considered as an effective self-programming process in developing a holistic human capital required by employers and the society. For Japanese students, the experience of conducting research in laboratory provides them with the opportunity to groom personality and human qualities that suit Japanese society. The laboratory prepares the students to be good citizens and marketable employees to the society.

Cohort system: The learning process requires time. Considerable period of time is needed to ensure the social interaction and apprenticeship culture among members in the laboratory to be robust and generates long-lasting impact.

Universities in Japan, especially for Engineering programs, set one year for undergraduate students to complete research thesis (sotsugyou ronbun) and two years for Masters students to complete their research works and submit final thesis (shushi ronbun). PhD students take three to four years (depending on performance), before qualify to obtain a PhD. Normally, they all Graduate On Time (GOT). Note that all programs are full-time.

Admission to all programs takes place simultaneously across Japan and students are categorized by cohort. For students this cohort system allows them to plan and manage time more efficiently because the time-frame for graduation is clear. It also encourages cross-cohort social interaction or senpai-kohai (senior-junior) relationship.

CONCLUSION

The Laboratory-Based Learning (LBL) methodology that is practiced in most research laboratories of science and engineering programs in Japan could be considered as an effective method of developing students that not only master technical skills and attain relevant knowledge but more significantly, the students are "engineered" to acquire three main positive attributes:

- Multi skills (technical and social)
- Practice of ethical work habits
- Nurturing of good social values

The same observation was personally observed by during his study at National University of Kumamoto. McGuire observed that these students are the group "that constitutes the rank and file of the engineering force" and that the focus of the program is "in developing a domestic army of highly trained engineers". In the real workplace, it is where the graduates excel through experiences gained from previous experiences as emphasized by Dewey (1897), "Every experience lives on in further experiences. Hence, the central problem of education is to select the kind of present experiences that live fruitfully and creatively in subsequent experiences".

LBL is a systematic and effective methodology for engineering students to attain the learning outcomes of attaining knowledge, developing skills and the nurturing of positive attitudes as documented in their respective curriculums. Therefore, LBL methodology is suggested to be adopted with some adjustment (if necessary), for undergraduate (final year student) and postgraduate program or any research-based program in university.

Those involve in curriculum design need to make several appropriate adjustments and adaptations before they could adopt entirely the LBL methodology. It depends very much upon the kind of students, the research works to be conducted, the availability of research laboratory and professor, the kind of supervision and mentoring needed as well as the targeted outcome decided upon. These elements need to be specified first before the LBL methodology is adapted.

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