A Fusion Program of Technology Management and Career Design in a Liberal Arts Curriculum for Engineers

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Abstract— This paper discusses models for the development of an educational program for technology management in a liberal arts curriculum at the undergraduate level for engineers, and analyses and evaluates the attitude changes of the learners who complete the program in 2014 and 2016. The programs developed are based on the concept of fusing technology management and career design. In this program, students learn mechanisms to promote novel value creation activities, select an industry and vocation that capitalizes on their own abilities, and cultivate the ability to create precise motivations through self-management and industry/company research. Some models are proposed and applied in the development of an educational program within the liberal arts program at Kanazawa Institute of Technology (KIT) in Japan.

Keywords— Engineering Education, Career Design, Management Education, Liberal Arts, Management Circle.

I. INTRODUCTION

Although there has been much discussion concerning the definition of and principles behind technology management [1] - also called management of technology - a consensus agreement has not yet been reached. However, many experts agree that as an academic discipline, technology management can be generally defined as “management studies for organizations that produce things using technology” [2]. In addition, around 2000, the Japanese Ministry of Economy, Trade and Industry defined it in management terms as, Management for businesses and organizations having technology at the core of their enterprises, for the purposes of carrying out technological development and continuous creation of next generation enterprises [3]. Regarding its name, the discipline is often called management of technology (MOT) in Japan, but sometimes engineering management, technology management, and technology innovation management as well.

Education programs for MOT are generally engineering graduate school programs and include courses in business administration science, industrial engineering, systems engineering, and other fields.

This paper proposes models for developing educational programs of technology management for a liberal arts curriculum at the undergraduate level for engineers, and to discuss with the results of a case study of developing such a program at Kanazawa Institute of Technology (KIT) in 2011 to 2016.

II. MODEL BUILDING AND TOOL DEVELOPMENT

A. Approach to fuse technology management and career design

This research project makes the following foundational assumptions about the act of management and management technology:

(1) Management is a systemic activity to accomplish a business objective.

(2) The function of management has two aspects, namely, planning and control (i.e. measuring the difference between the plan and the outcome and taking corrective actions when needed).

(3) The objective of the planning and control cycle (i.e. the management cycle) comprises the dual aspects of maintaining and challenging the status quo [4]; these aspects are inseparable. A challenge to the status quo is a challenge to attempt the unknown, and is accompanied by certain risks. To overcome these risks, activities associated with maintaining the status quo should be standardized. In other words, the pursuit of standardization confers a learning effect, which allows for added knowledge capacity. This capacity can be utilized to challenge the status quo.

(4) This learning effect associated with companywide improvement activities can be interpreted as a strategy by which a company can accrue management resources through sustained improvement efforts, such as in (3) above, The accumulated knowledge is attracting attention as intellectual assets, categorized in terms of corporate know-how, technological know-how and corporate culture.

Such intellectual assets increase the future value of a company. This is consistent with Drucker’s argument [5]:
Management technology in the 20th century has made a large contribution in enhancing the effect and effectiveness of the value creation of goods and services by incorporating scientific knowledge into business. However, businesses need to contribute now by utilizing scientific knowledge to create new scientific knowledge.

Here career refers to their professional life or professional experience[6]. Management that evidences their ability (i.e., management resources), depicts a vision for the future, and realizes such a vision has the following features. Management is nothing more than:

* the ability to recognize the management resources a learner lacks, such as skills and knowledge;
* the knowledge on how to utilize their time and place effectively and efficiently; and
* the ability to procure and accrue the management resources a learner lacks, to effectively and efficiently utilize such resources and maximize value creation.

In our study, career design is defined as the following cycle of activity:

1. Decide the direction and objectives of their future professional life or to formulate a ‘wish list’ to that end;
2. Create an action plan with set objectives and a timetable, or depict their vision, with a tool sometimes referred to as a roadmap[7].
3. Implement their plan and comprehend/ evaluate the difference between their plan and the results; in other words, create a record of themselves in action.

The following two issues first need to be addressed before a learner proceeds with continuing efforts for improvement:

1. The learner must consciously preserve a sense of management as a means of fulfilling their set dream. In other words, the learner must understand what they or their organization must overcome to grow.
2. The learner must upgrade their problem solving knowhow and skills, and continue to develop mechanisms and tools to achieve this. Here mechanisms and tools refer to their unique continuous learning methodology.

Point (1) above is a question of psychology, consciousness, and feelings, and thus falls within the realm of a motivational theory applied to management technol.

**B. Career design and the learning process model specifications**

Individuals each have our own sense of happiness, and strive to maintain or increase their personal our happiness.

Individuals carry out this pursuit of happiness as a learning activity, which can be depicted as the process shown in Fig. 1. Regardless of whether individuals are conscious of this process, knowledge acquisition, as shown in Fig. 1, is achieved through two forms of knowledge. The first is knowledge expressed through writings, diagrams, or equations, referred to as scientific or explicit knowledge. The second is knowledge gained through experience (sometimes referred to as tacit knowledge[8] or a form of knowledge that cannot be expressed in written or verbal forms. In either case, individuals continuously pursue a sense of happiness by understanding and utilizing acquired knowledge. If that knowledge is insufficient, individuals seek other means of acquisition. That is knowledge creation. Every individual can examine past emotions of joy, anger, pathos, and humor to understand the meaning of happiness. Such information can be compiled into a personal history (a methodology of analyzing our personality by plotting the positive and negative aspects of our emotions along a time axis) and analyzed.

**FIGURE 1 CONCEPTUAL DIAGRAM OF THE LEARNING PROCESS**

The first step in designing their career is to set the learner’s objectives in a way that can improve their sense of happiness. Because of this difference, their ability to sort, express, and communicate their personality (their value as a person) to a third party must be refined through mutual enlightenment. The word “value” refers to a universal character that everyone recognizes as good, regardless of personal preferences such as with regard to truth, virtue and beauty.

The next step is for the learner to continually sustain and improve their sense of happiness through their actions in society. To take such actions, the learner must examine the following questions regarding their learning process:

1. Does a learner understand what is necessary to establish and achieve their objectives?
2. Does the learner understand the strengths and weaknesses (what they need to augment) of the management resources (knowledge and ability) they have acquired and accrued as a result of their learning process?
3. Does the learner understand precisely how to add to their strengths and augment their weaknesses, and when they need to?

If the results of the learner’s self-examination are unsatisfactory, they need to improve their learning process.

Moreover, to efficiently improve the effectiveness of their learning, the learner must continuously upgrade the methods and processes by which they go about learning. One way to do this is a PDCA cycle, perhaps with reference to the learning pyramid[9], through which the learner can obtain an efficient
learning method best suited to their situation and that can challenge their status quo.

III. MANAGEMENT CYCLE MODEL FOR THE DUAL CREATION OF HUMAN AND SOCIAL VALUES

In his research on why humans behave as they do, Maslow[10] concluded that individuals act to satisfy their needs. Maslow claimed that humans have five types of needs, which form a hierarchical structure in which the focus of their needs change sequentially from their baser needs to higher needs. The highest need of the five needs is for self-fulfillment which is the desire to maximize one’s potential and develop oneself. Accordingly, if an individual’s work is based on this need for self-fulfillment, they are attempting to develop their potential through the act of working.

The quality of working life (QWL) model[11] is viewed as a basic companywide attempt at Kaizen or improvement. If individuals view daily lives as a 24-hour cycle, one third of the day is spent at work. Therefore, the idea behind this concept is that the needs of society and the individual are compatible. To improve their quality of life is to improve their quality of work resulting in better products and services, thus contributing to society and improving their personal life.

While what makes people happy differs between individuals, if working is an act to satisfy their needs, and if the need for self-fulfillment ranks highest among all human needs, it is important that individuals set their objectives while considering work values that lead to improvement in their quality of life and high satisfaction, such that their work can continue to their purpose in life.

A career design developed to fulfill a learner’s vision must take account into how the resources individuals has thus far acquired and accrued will bring the learner closer to achieving that vision. The same can be said about of how a learner goes about learning, i.e., a learner’s learning process. Once a learner has discovered which way to direct their learning process to achieve or complete their ‘wish list,’ learning becomes a joy, and a continual cycle of management(i.e., PDCA) take it a drive towards happiness. In other words, career design is the first step towards a learner creating their personal human values. Drafting a career design means a learner will no doubt be propelled by the urge to act, rather than being forced to act.

The companywide Kaizen movement[12], which originated in Japan and is embraced in other parts of the world, is acknowledged as effective means of accelerating an enterprise’s intellectual asset formation. Activities supported by this movement include small group activities, one type of which - Quality Control (QC) Circle activities - is underlain by three basic principles[13]:

*Contribute to the improvement and development of the enterprise.

*Respect humankind and build a worthwhile and happy workplace.

*Fulfil your potential to reach heights that may seem impossible.

Small group activities originated in the form of voluntary study groups among small groups of employees at the same workplace. Representing the ultimate learning process of learning by working, this form of organized learning constitutes the basis of the Kaizen movement.

Meanwhile, an organization has its own values and standards of conduct. These constitute a type of intellectual property embodied in corporate culture or organizational features and are expressed in the form of a company’s guiding precepts/credo or corporate philosophy and disclosed to the public. These guiding principles represent the organization’s social values. Internally, they represent a common code of conduct and a wish list that organizational members should strive to fulfill. A member’s management activities are, in effect, acts to realize this organizational vision. However, individuals have their own wish lists and accordingly act to fulfill their own purposes in life and personal dreams. Therefore, the higher the commonality between the creation of human values (or actions the individual takes towards self-fulfillment) and the creation of social values (or actions the corporate organization takes to fulfill them), the stronger the Kaizen effects.

Fig. 2 is a conceptual diagram of the learning process as a Kaizen activity consequent to the dual creation acts of the individual striving to create human values and the organization striving to create social values. In Fig. 2, challenging the status quo is evidence of continuous progress. To challenge the status quo, an individual must establish a vision for them to take action and close the gap between their present state and the desired state on their wish list.

A learner’s vision refers to the series of measures, the timetable for those measures, and the final objectives of the learner’s wish list. This is sometimes referred to as a roadmap. For instance, learners can envision themselves one month from now, a year from now, and five years into the future. To the end of dual creation by individuals, who continuously pursue their individual happiness, and the enterprise, which strives to perpetuate its development, learning occurs for both the individual and the organization along the flowchart visualized in Fig. 2. Two distinct styles of learning are required to achieve this dual creation: one is a conservative learning style, or single loop learning, where - once the acquired knowledge is understood - the objective is to maintain the status quo by reinforcing one’s abilities to maintain it through the repetitive use of knowledge and experience; the other is an aggressive learning style called double loop learning[14], where the objective is to challenge the status quo by setting unresolved, highly developmental tasks that exceed the limits of existing knowledge and experience. It is important to note, however, that an aggressive learning style sometimes results in failures. To ease a learner’s potential resulting fears and indecision, they must first gain confidence by employing the stable conservative learning style and developing the ability to learn from failures.

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FIGURE 2 THE MANAGEMENT CYCLE MODEL FOR DUAL CREATION OF HUMAN AND SOCIAL VALUES

IV. DEVELOPMENT OF EDUCATIONAL TOOLS FOR NOTATION OF A CAREER DESIGN USING FOUR SCREENS

Based on the models mentioned above, we developed a “four screens” educational tool and procedures to draft a career design.

A. Sketch of the Learner’s Present State

This screen prompts a learner to list their acquired management resources, examine their efforts to accumulate knowledge, and write down the results. In other words, the learner is prompted to ‘know themselves’. However, a learner can only see their face with the help of a mirror. Three methods can be used to obtain such a mirror:

(a) Create a personal history that describes the events the learner has experienced to date.
(b) Describe oneself as viewed from the perspective of those around you, by a method such as the Johari Window[15].
(c) Undergo an aptitude test.

B. Sketch of the learner’s wishes

In this screen, the wish list, the learner considers the following questions in order to envision themselves ten years from now:

(a) In what type of business and what industry will I be working?
(b) What sort of work will I be doing?
(c) What sort of people will I be working with?
(d) What sort of people will I be working for? i.e., target market and customers (whose approval does the learner seek?)
(e) What technological innovations are the products or services that I wish to offer subject to?

C. Sketch of the learner’s vision

Learner compares their present state with their wish list. Likely, the learner will observe a disparity between the two, since the absence of any disparity suggests that the learner’s dreams have already been fulfilled. The learner proceeds under the premise a disparity exists between their wish list and their present state. Once a disparity is confirmed, the next step is to devise a number of strategies to eliminate this disparity using a “strengths, weaknesses, opportunities, and threats (SWOT)” analysis[16]. The learner considers some of the following points:

(a) Internal resources: the learner concentrates on listing their present strengths and weaknesses.
(b) External environment: the learner examines their opportunities and threats, concentrating on the following aspects of their wish list:
   * Conditions surrounding the business and industry.
   * Conditions surrounding the market and customers.
   * Circumstances related to products and services.

Next, from the combination of internal resources and external environment, the learner cross analyzes the fulfillment method(s) against the wish list objectives. Furthermore, the learner should:

(i) set objectives that are specific, measurable, and attainable;
(ii) embrace values that are relevant to the organization’s values, and ensure the organization does likewise for the learner’s individual values; and
(iii) set a time limit to achieve those objectives.

Finally, the learner creates a roadmap by placing each of the strategies corresponding to the set objectives sequentially along a time axis.

D. Sketch of the learner in action

In this screen, the learner creates an action plan for their vision, assembles their track record data, and evaluates their achievements to date. If the learner finds a large gap between their action plan and their track record, they must consider measures to correct this. Additionally, each screen (i.e., each quadrant in Fig. 3) is subject to review and consequent revision. Moreover, a learner can increase their motivation by showing the quadrants to others and committing themselves publicly to achieving their objectives. It is also recommended that the learner keep this chart to hand as a tool for further inspiration. Fig. 3 is a sample template of the quadrants described above.

E. Improvement of the narrative of the earner’s quadrants

Once the learner has completed filling out their quadrants, they add the finishing touches by reviewing each item in each quadrant, and they try to envisage a narrative relationship between the quadrants. First, the learner confirms the disparity between their present state and future visions. Then, they develop a reinforcement plan to eliminate this disparity through plotting objectives and methods along a time axis. The learner repeats this exercise cycle to improve their personal quadrant chart shown in Fig.3.
V. EDUCATIONAL PROGRAM DEVELOPED

For the program to achieve high educational effectiveness in a technology based liberal arts curriculum of KIT, the educational objectives were established by using the educational resources of KIT which have competitive advantages. As the result, the learning and educational objectives of the program were set as the following.

Technology management is a framework to make full use of technology in order to develop, maintain, and improve systems as well as products and services that are useful for society. In this course, students will understand mechanisms and operations to promote novel value creation activities which business organizations adapt to the environment via technology management. After understanding technology management, students will select a type of industry and vocation that makes use of their own abilities, and cultivate the ability to create precise motivations. The course was developed based on the ADDIE model of instructional systems design (ID)[17], and also reflected the University’s founding principles and code of conduct. The flipped class-room-learning model is also employed, with a focus on co-operative learning.

As shown in Fig.4, the program had 11 lecture titles for each educational goal. Group work in each topic, which uses cooperative learning, ensures that learners have the opportunities to experience both self-enlightenment and mutual enlightenment processes, which cultivate meta-cognitive skills, as they need to think carefully about their own thinking and learning[18]. Subsequent group-work, consisting of practical problems that reinforce learning items, enhances learner affectivity and gives them experience with applied techniques for the knowledge and skills they have acquired. The aim is to create a place that encourages a deeper understanding of the learning items. Also, Fig.4 shows the process by which learners create and improve the four-panel career design exercise and how it relates to their creation of a learning portfolio as part of the group-work.

Table 1 shows learning process in the program. The work is classified into two types: the first is a question and answer session concerning knowledge associated with educational goals, and the second is a problem-solving approach that requires the application of knowledge and the collection and analysis of data and information. We instituted two activities to improve student knowledge and awareness of the designated learning items: group-work for students to teach and learn from each other and the creation and advance preparation of homework materials. Learners prepare for class using homework materials, list the questions they have, and address them in that day’s lesson. Students discuss their questions among themselves at the beginning of the lecture and develop a single answer. If no agreement or consensus on an answer is reached, the student leader asks the teacher and obtains the answer. The leader is nominated by the members of a group.
This program design intends to cultivate learners who can effect organizational change by thinking, behaving, and changing themselves. Therefore, to efficiently improve their learning effectiveness, learners must continually upgrade the methods and processes by which they go about learning. One way to do this is to use a PDCA cycle, perhaps with reference to the learning pyramid[9], through which the learner can obtain an efficient learning method best suited to their situation, and which can challenge their status quo.

VI. ATTITUDE CHANGES OF LEARNERS

Fig. 5 shows the changes during three years in the self-evaluation results for practical abilities corresponding to KIT-IDEALS of the students. KIT-IDEALS reflects the school community values that the students, Board of Directors, faculty members of KIT, and staff are expected to always be aware of, put into practice, and respect to further improve in their campus activities. These are the sophomore class which is before taking the course, junior class which is under taking the course, and senior class which is after completion of the course. This figure shows that the students improved in integrity and self-realization of their ability to create the values prized by the school community with significance level 5% in hypothesis tests work in statistics.

Fig. 6 shows the kinds of attitude changes that attendees became aware of as a result of taking this course. These are average levels of the integrated abilities of the learners who took the course in 2014 and 2015. Integrated abilities consist of five evaluation items. The learning abilities are supported mainly by professional education curriculum. And basic academic education curriculum educates human abilities. The performances of both curriculum are evaluated by the integrated abilities’ criteria which were consisted of the following five abilities.

(a) Knowledge acquisition ability,
(b) Ability to think, reason, and create,
(c) Collaboration and leadership,
(d) Ability to present, express, and communicate,
(e) Positive attitude to continue learning.

All abilities have the difference between 2015 and 2014 with significance level 5%.

Fig. 7 shows the attitude change of the learners who completed the course in 2015 and 2016. This survey was taken in the final lecture in the course. About 90% of the learners evaluated that they changed their own attitudes for their future.

VII. CONCLUSIONS

The program has been run from 2014 as a two-unit compulsory subject for third-year undergraduate students of KIT. Over the following three years, 4964 students took the course under the instruction of four teachers. It took three years for developing the concept, models and tools of the program. Nonetheless, we continue to make improvements to the program to this day. Over these 3 years, increased satisfaction
has been visible over time in data of surveys given to students after completing the program. The program has additionally had positive effects on practical skills related to our School's code of conduct, as well as on attitude changes.

Cooperative learning was incorporated from the first year, through the design, development, and improvement of the group-work worksheets. Efforts to develop e-learning materials proceeded from 2015: we analyzed the effects of homework conditions on learning outcomes, and made improvements to educational materials based on the results. Based on these efforts, we trialed two kinds of group-work - i.e., the homework comprehension check and group exercises—in the first half of the lecture, and endeavored to confer flipped classroom qualities to the lecture. In addition, we proceeded to make rubrics[19] for report and presentation exercises (i.e., joint presentation of the four-panel exercise).

The above efforts create a mechanism to provide learners with a place to experience learning and teaching. This allows them to improve their abilities to foster both personal development and the development of their peers, which in turn improve their desire to learn in a self-directed way. These activities serve as a model for “learning through work”, in the form of improvement activities done in small groups, which is considered to be one factor that can ensure the competitive superiority of Japanese industries.

The above findings suggest that our program development successfully achieved the designated outcomes.

One future challenge is evolving the program such that it provides learners with a place where they can proactively endeavor to realize their dreams, continuously acquire learning skills, and seek personal happiness.

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