Toward Sustainable Learning Economy through a Block-chain based Management System

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Abstract: This paper proposes Sustainable Learning Economy (SLE) based on market principles. SLE will utilize the blockchain technology in order to let learners trade their learning results in cryptocurrencies, which in turn gives the learners a strong motivation to acquire the knowledge independently to gain their rewards. The main challenge in SLE has been guaranteeing learning quality; however, this could be resolved using competency-based learning (CBL), an efficient learning method to prioritize acquired knowledge over knowledge acquisition. Unfortunately, due to social, corporate, and educational demands, competency models require significant time, manpower, and expertise. While Conventional Competency Management Systems (CMS) reduces costs by providing an integrated environment for CBL operations, it is not able to reduce development costs. Therefore, to reduce development costs, this paper developed a Smart CMS, which harnessed concepts of distributed artificial intelligence, the power of internet resources, and network analysis technology to automatically develop competencies tailored to the purpose, strengths, and characteristics of individual learners.

1 INTRODUCTION

In modern knowledge-based societies, people need to have open learning places in which they can use the knowledge learned from society and continue to learn for the rest of their lives. Traditional school systems have supported the modernization of society since the Industrial Revolution, however, formal education structures do not allow for constantly changing knowledge and are unable to respond to the diverse demands of diverse people. Therefore, the knowledge gained from formal school education is limited, which is a major challenge to providing equal access to quality lifelong learning education for all.

The Massive Open Online Courses (MOOCs) movement that boomed in the United States in 2012 was expected to provide all people with an open learning place. However, the MOOCs learning outcomes have not been able to provide a learning system for the knowledge-based society that leads to employment or the innovations needed for a prosperous life. Current MOOCs guarantee learning outcomes using a traditional system for which the respective institutions of higher education provide the completion certificate; that is, as the MOOCs evaluation system is the same as for traditional schools, it does not provide an open learning environment and, therefore, has been no more successful than traditional universities.

Behavioral Competency-Based Learning (CBL) (Wesselink, Lans, Mulder, & Biemans, 2003; Barrick, 2017), which has been adopted by many

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universities in the United States, has been successful in connecting learning outcomes to the needs of the social and labor markets. However, the competencies are defined based on the needs of organizations that provide the CBL and, therefore, are unsuitable for others outside the company. Furthermore, the competency development, and maintenance model is expensive and constrained by various licenses.

To cope with these issues, this paper proposes a Competency Management System (CMS), which harnesses concepts of distributed artificial intelligence (DAI) to automatically determine competency construction and learning evaluations and provide the required framework for learner-oriented CBL; therefore, it can offer an open learning space with socially useful learning outcomes for all people.

2 DECENTRALIZED EDUCATION

Illich (1973) criticized traditional schools claiming that knowledge generally comes not from the school through teachers, but from the outside society. Illich believed that to cope with the increasingly complex modern society, informal education over a lifetime would be more useful, for which he proposed a decentralized education system called the Learning Web. However, while decentralized education could be a valuable social infrastructure, there are three main challenges.

First, how can learners be motivated? In traditional schools, students are incentivized by moving up to the next grade or in the last stage by gaining the requirements to get a job. However, as decentralized education has no clear learning stages or graduation concepts, it does not have the same motivations or incentives.

Second, as decentralized education does not exist within institutions such as schools, there is no way to guarantee the education quality, as conventional independent organization quality assurance reviews are mechanisms designed for traditional centralized management systems.

Third, how can the learning outcomes be evaluated? In traditional schools, there are standards applied to assess whether the learner has acquired the knowledge, which is further tested through exams; however, it is difficult to set standards for the various types of learning in decentralized education.

3 LEARNING ECONOMY

To solve these decentralized education challenges for the learning economy, this paper proposes a new informal education mechanism that uses blockchain (Figure 1).

In the learning economy (Hori, Ono, Miyashita, Kita, 2019), learners (not teachers or schools) earn cryptocurrencies from their daily activity learning outcomes, which gives the learners a strong motivation to independently acquire and/or update their knowledge faster than in traditional schools.

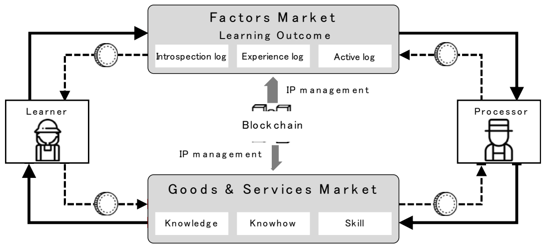

Figure 1: Learning economy.

The learning economy market principles allow for an evaluation of the learning outcome quality and the quality assurance; that is, the market economy principle states that in the learning economy, low-quality outcomes are eliminated through competition and the outcome that people best value is widely circulated.

4 LEARNING ECONOMY CHALLENGES

There are drawbacks as it may take a long time for the market to generate reasonable learning quality results when evaluating learning value based on market competition. For example, if inferior knowledge in the learning economy is initially highly valued, it may take some time for the market principles to update the knowledge. Therefore, further refinements are needed to ensure these types of poor knowledge inputs are corrected as quickly as possible to maintain quality assurance.

We have conducted a study in which the learner was recording their learning outcomes on a blockchain and trading the outcomes using virtual currencies (Hori *et al.*, 2018), with the quality assurance function effectiveness being based on the principle of competition; however, there were errors found that could not be corrected in some cases. Therefore, this paper introduces a new CBL learning economy concept, which guarantees the learning quality as quickly as possible.

5 COMPETENCY

The definition of competency might be ambiguous because the perception in this context is different from its meaning in business and education. The National Postsecondary Education Cooperative stated that learners gain competency when they have mastered the skills, abilities, and knowledge associated with that particular competency (Jones & Voorhees, 2002).

CBL was developed as an educational approach to assess competency based on performance. As the competencies were evaluated based only on the acquired knowledge and skills and not the learning process, such as attendance, attitude, and effort, CBL was initially seen as a potential method for transforming traditional education. By evaluating the learning process, it was expected that people would be able to effectively develop knowledge and provide society with a high-quality workforce; however, CBL development was found to be expensive in terms of time and costs.

The development of CBL models has, therefore, been challenging, and costly because of the need to reflect market demands, learner demands, and academic expectations. Further, to continue to meet the needs of the community, competency models need to be constantly updated and developed in line with progress in science, technology, and society. For example, the Western Governors University organized and is still working with a program council of academic and industry experts to develop their CBL model (Johnstone & Soares, 2014; Oblinger, 2012). CBL models have only been used in schools, corporations, and other organizations, and each industry, and specialty field has built and customized standard generic competency models; therefore, there has been insufficient CBL model development.

6 COMPETENCY BASED LEARNING

There have been three main approaches to developing CBL models: a behavioral approach, a generic approach, and a comprehensive approach. Table 1 details the characteristics of each of these, and, in this section, the features of these three approaches and the proposed CBL are elucidated.

Table 1: Three types competency.

	Behavioristic approach	Generic approach	Comprehensive approach
Abilities target	Competencies and tasks required to perform duties	Competencies and tasks required for all occupations	Competencies for cultivating qualities and personalities required for the times we live in

6.1 Behaviouristic Competency

The behavioral approach is focused on acquiring the competencies to perform a specific task (Wesselink *et al.*, 2003; Barrick, 2017). The competency can be broken down into several units that focus on the specific tasks required to perform the task; therefore, each unit focuses on task achievement and does not include learning assessments during the learning time as in the Carnegie unit. Further, as the competency is divided into easily manageable tasks, it can be easily, and efficiently managed. Therefore, because the units can be easily processed by information systems, it has a high affinity with online education and, consequently, has been widely adopted for job training at universities, companies, and trade schools in some countries as it has been recognized as a viable educational method for developing specific skills for specific tasks.

CBL, however, has been criticized for placing too much emphasis on performing specific tasks and less time on thinking and/or comprehension (Barnett, 1994), as learning should essentially require that learners autonomously discover and create their own knowledge. As the goal of the CBL behavioral approach is to attain the competencies defined by the organization to achieve the results expected by the organization, it is unsuitable for open online education as it is unable to address the needs and backgrounds of a diverse audience.

6.2 Generic Competency

To resolve some of the drawbacks of the behavioral approach, both the basic abilities for the entire occupation and the abilities and tasks necessary for a specific job are required. Therefore, the generic approach expanded the basic skills acquisition to cover the skills needed to function effectively within the occupation, such as critical thinking skills and problem-solving skills. However, the generic approach is the same as the behavioral approach because as the learning assessment is based on achieving the unit competencies, it also has a high affinity with information systems and online education, but does not address the diverse audiences in open online education. The generic approach has also been criticized for not fully developing an individual's overall abilities to adapt to complex environments or to create knowledge. Further, to define, and develop the competencies for both the generic and behavioral approaches require a great deal of time, effort, and cost.

6.3 Comprehensive Competency

The comprehensive approach does not focus on specific professional development; rather, it focuses on education that can cultivate the qualities and personalities required by the times we live in. this approach is based on the hypothesis that every human ability is not merely a combination of competencies and cannot be reduced to component parts or elements. In this approach, the learning process is also subject to learning evaluation. Competencies that are proposed by the OECD's DeSeCo project and the Tuning Academy in the Bologna process also take this position.

The challenges of the comprehensive approach are that the competencies are difficult to structure and cannot be systematized, and for comprehensive development, strong project-based education, and active learning skills are required. Therefore, as the teachers are required to have these high-level skills and only a limited number of learners can be taught at once, this approach is unsuitable for large-scale online education for reason that the teachers need to teach many students simultaneously.

7 CMS

Traditional CMS, which is designed based on the behavioral approach, requires that the CBL be integrated with human resources management and a Learning Management System to ensure the storage, maintenance, and tracking of the competencies and performances within an organization.

While the CMS is used to manage the CBL, it does not include the development of the competencies, which is a laborious, expensive process. Therefore, several studies have intelligent support functions to generate competencies, such as a CBL curriculum generator and a learner skill gap measure. However, these proposed systems did not include the automatic generation of the competencies themselves but only suggested that the manually created competencies be automated.

CMS is part of enterprise knowledge management and has been widely researched and developed since the early 2010s in Europe and the United States (Draganidis, & Mentzas, 2006.). Table 1 shows the major CMS components.

Systems for the standardization of competency metadata have been proposed, such as IEEE RCD, IMS-RDCEO, and HR-XML, and competency model developments to reduce the time and efforts costs have included using ontology for the evaluation and development of individual competencies (Fazel-Zarandi & Fox, 2012; Lundqvist & Williams, 2008; Draganidis, Chamopoulou & Mentzas, 2006; Schmidt & Kunzmann, 2006).

Table 2: Major CMS component.

Component	Description
Definition	Clarify goals, identify and define required competencies
Model	Assemble competencies for each learner and organization attribute, such as department, job title, and characteristics
Learning method	Learn based on competency.
Evaluation	The degree of attainment of competencies
Component	Description

8 NETWORK GRAPH

Competencies can be seen to be bipartite graphs that link task ability and knowledge nodes to skills ability and knowledge nodes. If the tasks–skills combinations are represented using a bipartite network graph method, optimal tasks, and skills composition can be naturally derived. For example, Figure 2 shows part of an information technology (IT) competency graph, in which the task software utilization support node is linked to multiple skills nodes for a range of IT knowledge.

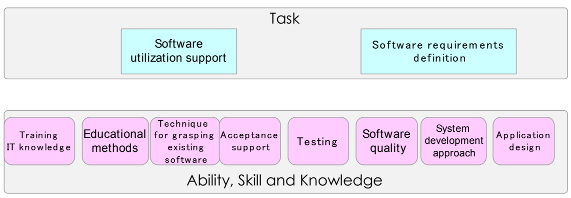

Figure 2: Bipartite competency graphs.

8.1 Analysis of a Generic Competency

To confirm the effectiveness of the network graph method, an existing generic competency, the "i Competency Dictionary (iCD)," was analyzed (https://www.ipa.go.jp/english/humandev/icd.html), which is a freely available competency dictionary consisting of 4,500 task dictionaries and 10,000 skill dictionaries for human IT development published by the Information Processing Agency Japan. iCD sets the global standards for IT human resources, with the Enterprise IT Body of Knowledge of the IEEE referring to the iCD as the Enterprise IT framework for Asia (IEEE, 2017).

This dictionary was therefore used in this paper to represent the tasks and skills combination on a bipartite graph.

This section gives an overview of iCD and then reports on the results of the iCD analysis using a network graph.

8.1.1 Task Dictionary

iCD is composed of a task dictionary and a skill dictionary, with the task dictionary having the following three hierarchies:

(Large classification) Functions required in the organization

(Middle classification) Business of the organization

(Small classification) Individual business

The individual tasks in the small classification, therefore, have the smallest granularity. In this paper, a small classification task is simply called a task. The task dictionary covers almost all tasks considered necessary by IT-related companies, from development related tasks to evaluation, improvement, management, and control.

8.1.2 Skills Dictionary

The skills dictionary consists of the following three hierarchies:

(Large classification) Skills category

(Middle classification) Skills classification

(Small classification) Skills item

In this paper, the small classification skills are simply called skills.

8.2 Results of Analysis

The igraph R package network graph method was employed to analyze the competency model, with the primary graph analysis being on the node relationships between the iCD tasks, skills, and related knowledge. As the iCD assigns different codes to related knowledge that has the same wording, the related knowledge with the same wording was connected to the same related knowledge, and the codes were reassigned.

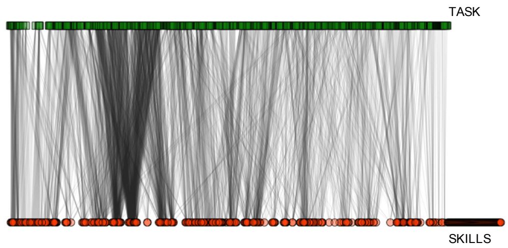

Figure 3: Bipartite graph of tasks and skills.

Figure 3 shows a bipartite graph for the iCD task–skill and skill–knowledge relationships, and Figure 4 shows a histogram of the frequencies for the edge of the bipartite graph for the task–skill and skill–knowledge. From Figure 4, it can be seen that all four graphs have corresponding n-to-n relationships and scale-free or power-law scaling, which means that multiple skills need to be acquired to perform some specific tasks, some specific skills are needed for multiple tasks, a range of knowledge is needed to acquire a specific skill, and some knowledge is required for multiple skills.

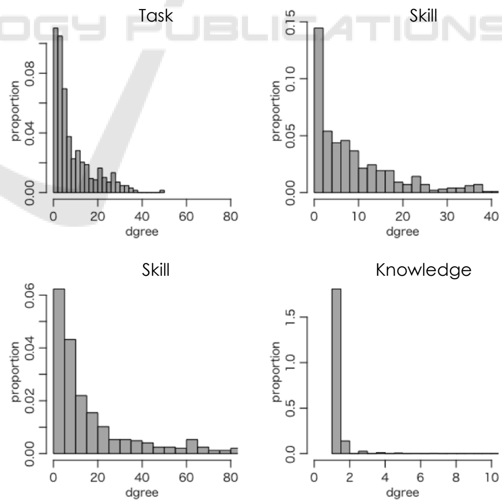

Figure 4: Histograms for order distribution.

To confirm these observations, the distribution of each node was checked, as shown in Figure 5. The upper left figure in Figure 5 shows a logarithmic graph that counts the edges of each task-side node for the task–skill relationships and permutates them in the order of frequency. In the same way, the upper right figure shows the logarithmic edge count for each skill-side node for the task–skill relationships. The lower part of Figure 5 shows a graph that counts the edges of each node for the skill–knowledge relationships.

The linear approximation for the task-side edges for the task–skill relationships was 5.40-1.20log (x) R2 = 0.75 (upper left in Figure 5), and the linear approximation for the skills side was 5.13-1.27log (x) R2 =0.78 (upper right in Figure 5). The linear approximation for the skills side of the skill–knowledge relationships was 5.10-1.24log (x) R2 = 0.78 (lower left in Figure 5), and the linear approximation for the knowledge side of the skill–knowledge relationships was 8.89-3.56log (knowledge) x) R2 = 0.98 (lower right in Figure 5). These results were found to fit a straight line. If the degree of the edges connected between the nodes is scale-free, it means that the value or utility of each node differs significantly.

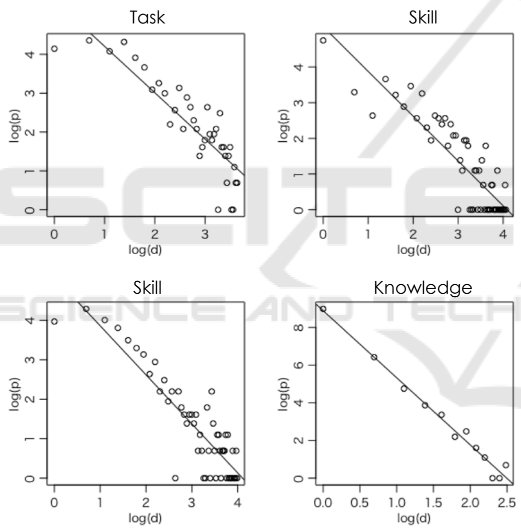

Figure 5: Logarithmic graph of degree distribution.

8.3 Analysis Discussion

The iCD competency model analysis suggested that the competency model was a scale-free network for the task–skill and skill–knowledge relationships. If a competency exists in a scale-free network, 1) specific skills are required for many tasks, and specific knowledge is required for many skills; 2) a small number of tasks require many skills, and a few skills require a wide range of knowledge; 3) the competencies are constantly growing; 4) newly established tasks, skills, and knowledge during the growth process are connected to existing task and skills node hubs in many cases; 5) the competency model structure does not change significantly. For a competency that has this type of structure, the skills, tasks, and knowledge set allows for a CMS to autonomously build the competencies.

9 SMART CMS

9.1 Overview

Using a DAI, a smart competency management system (S-CMS) suitable for a scale-free competency model was built that was able to generate competencies without the need for excessive human time or effort.

Figure 6 shows the conceptual diagram for S-CMS. The S-CMS stores the competencies in a graph-structure format, and then constructs the competencies using the DAI.

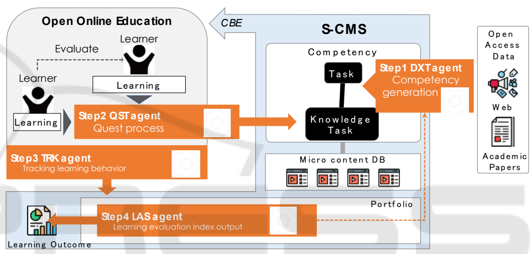

Figure 6: Overview of the S-CMS.

The S-CMS was implemented using four types of DAI agents:

Data extract (DXT) agent, which has a competency generation function.

First, the DXT agent generates the task, skills, and knowledge learning lists from keywords that are extracted from internet resources such as open access academic papers social networking service hashtags. Then, the DXT agent performs graph analysis on the lists, after which each list item is embedded as a node in a network graph, which is the generated competency. Simultaneously, the DXT agent collects learning content from open education resources from which it atomizes the micro content. Finally, the DXT agent uses a text mining engine to construct the learning materials that link the competency to the micro contents.

The Quest (QST) agent handles knowledge creation using a search process.

While the DXT agent provides the competency tasks, skills, and knowledge, and the corresponding learning materials to the learners, the QST agents provide the knowledge learners need to search for the skills and learning materials. The QST agent evaluates the relevance of the competencies using a graph search algorithm and outputs appropriate search results that match the learner's purpose. If a new knowledge or skill item is discovered and is used by other learners, it is recorded as a reputation in the portfolio of this learner.

The Tracking (TRK) agent tracks the learning behaviors.
The TRK agent tracks the learners' learning behaviors and records the learning history, search processes, and reputations in portfolios.

The Learning Analytics (LAS) agent outputs the quantitative learning indices.
The LAS agent compares the learning data recorded in the portfolio with the S-CMS competencies and outputs the skill gap as a quantitative learning evaluation index, which makes it possible to reflect on the learner and automatically evaluate the learning. The accumulated data is then used to retrain the DXT agent to ensure the S-CMS competency is more accurate.

9.2 Modelling Competency by Graph Structure

Previous studies on intelligent CMS models have employed domain ontology to define the body of knowledge in a field (Wesselink *et al.*, 2003). However, in open online education, using domain ontology for CMS competency modeling is not suitable because of its complicated structure and the diversity of people using the CLE. The S-CMS focuses on the structure of competency problems and the knowledge and skills to solve those problems and uses a network graph to provide a visual overview of the competencies to enable the agent training analysis technology.

9.3 S-CMS using Blockchain in the Learning Economy

The architecture of S-CMS is illustrated in Figure 7. To realize the architecture, the following discussions are important.

Adopting S-CMS into the learning economy model will enable us to measure learning outcomes in the marketing procedures. In S-CMS, after the DXT agent generates the task, skills, and knowledge learning lists, while a learner searches for knowledge and skills using QST agent to solve a specific task, TRK agent recorded the learner's search processes on the blockchain along with the learner's task.

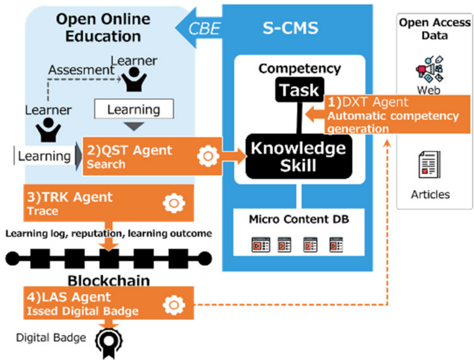

Figure 7: The S-CMS using blockchain.

The recorded learning results should be traded between the learners in the learning market using virtual currency or transactions. Such transactions will be utilized as a new quality assurance method of the learning results by the learners' peer review. Because the incentive in the market is highly motivated by learners, the quality assurance to be evaluated in the market differs in getting the quick results. Finally, the LAS agent issues digital badges for the learning outcome according to the market evaluation.

Using the blockchain mechanism, the proposed architecture has the scale-free features of the learning economy. The dynamic construction of learning economy might supress erroneous information, if CBL models would be properly incorporated into the learning economy.

10 CONCLUDING REMARKS

In this paper, it has been experimentally confirmed that in the learning economy, trading based on the market economy results in a scale-free structure. However, the proposed scale-free structure might explosively generate incorrect information (Lundqvist *et al*., 2008). This must also be tackled.

Using the network graph method, this paper has analyzed the structure of current generic scale-free competency models, and to reduce the cost of developing competency models, proposed an S-CMS that used network graphs and DAI

The S-CMS CBL model uses DAI to generate competencies and allows learners to search for useful knowledge and skills through trial and error and discover knowledge and ideas not highlighted by experts.

As the learning economy has a scale-free competency structure and targets a very wide range of learning, the proposed S-CMS can construct suitable complex competency spaces using the DAI and network graphs that cover the entire learning economy without the need for human intervention. Introducing CBL into the learning economy would also provide an effective, efficient quality assurance system that takes less time than quality assurance systems based on market principles that require constant correction, which reduces the learners' re-learning burden when there is incorrect knowledge in the learning market.

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