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Design of a Performance-Oriented Learning Ontology

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Abstract: E-Learning is increasingly being used by various organizations as an emergent approach for enhancing the skills of knowledge workers. Different from school environment, learning in organizations is built on practical tasks and work situations with the aim of serving organizational goals. This study incorporates performance measurement into learning ontology to clarify organizational goals and individual learning needs, and link them to e-learning applications. The key idea lies in a Key Performance Indicator (KPI) model, where the organizational mission and vision are translated into a set of key performance targets for driving learning towards the goal of improving work performance.

Keywords: Ontology, performance, e-learning

Introduction

E-Learning is increasingly being used by various organizations as an emergent approach for enhancing the skills of knowledge workers. Different from school environment, learning in organizations is built on practical tasks and work situations with the aim of serving organizational goals. To facilitate this requirement, a performance-oriented learning ontology is proposed in this study. This ontology uses performance measurement to clarify organizational goals and individual learning needs, and links them to e-learning applications. The key idea lies in a Key Performance Indicator (KPI) model, where organizational mission and vision are translated into a set of key performance targets that drive learning towards the goal of improving work performance. To demonstrate the effectiveness of the approach, a prototype workplace e-learning system has been developed with relevant experiments used to evaluate the effectiveness of the approach.

1. Background

Companies and other organizations face a permanent change due to various emerging challenges including globalization, economic pressures, and the changing nature of work. To be successful, employees of organizations have to learn continuously to cope with the change. E-Learning, as an emerging approach for enhancing the skills of knowledge workers, is increasingly being used by organizations [8]. However, most existing e-learning studies are based in educational institutions [5]. Different from school environment, learning in organizations is built on practical tasks and work situations with the aim of serving organizational goals. As a result, most e-learning applications fail to meet the needs of learners and ultimately fail to serve the organization's quest for success in the knowledge economy [11, 12].

In this study, we propose a performance-oriented learning ontology to improve e-learning development in the workplace settings. Ontology is a formal representation of a set of concepts and their relationships in a domain using machine languages and semantic annotations [2]. It

supports human-computer communication on a semantic basis. This study incorporates performance measurement into learning ontology to clarify organizational goals and individual learning needs, and link them to e-learning applications. The key idea lies in a Key Performance Indicator (KPI) model, where the organizational mission and vision are translated into a set of key performance targets for driving learning towards the goal of improving work performance. The KPI model helps an employee identify performance measures for his/her position, capabilities to be developed to improve the performance, knowledge topics relevant to the capability, and learning resources under the knowledge topic. This conceptualization makes organizational goals accomplishable by showing a clear picture to each individual as to what is important and what they need to learn.

2. Conceptual Framework

Performance measurement is used by organizations as a procedure to improve performance by setting performance objectives, assessing performance, collecting and analyzing performance data, and utilizing performance results to drive further development. Key Performance Indicator (KPIs) used in this study are financial and non-financial metrics used to help an organization define and measure progress towards organizational goals [7]. A set of KPIs can be set up to represent a set of measures focusing on different aspects of organizational and individual performance that are critical for the success of the organization [9]. The KPI framework should be designed based on an organization's structure and job system. The KPI framework consists of three levels: organizational level; business unit level; and position level. KPIs at the *organizational level* are defined according to business goals and strategies of the organization. Based on the organizational KPIs, the KPIs at the *unit level* for each business unit can be derived. Based on the unit KPIs, the KPIs at the *position level* for each job position within the unit are defined. In this study, we focus on KPIs at the position level which have a closer relationship with e-learning in the workplace.

The KPI framework has special meaning to workplace learning which involves organizational strategy, structure, and systems. KPI bridges the gap between an organization's mission and its employees' targets, making organizational goals accomplishable. KPI can be used to help employees set up rational learning objectives according to the knowledge gap. It can be used as a systemic scheme to organize and manage learning resources and activities in line with work context and performance requirement. Further, KPI can be used to identify each individual's work context and expertise to support social learning and knowledge sharing towards the goal to improve work performance [12].

In this study, ontology is used to conceptualize the KPI-oriented learning environment into a machine-readable format. Ontology is a formal representation of a set of concepts within a domain and the relationships between those concepts; it is defined as "formal, explicit specification of a shared conceptualization" [2]. Ontology creates a machine-readable conceptual basis for communication between humans and computers. Ontology-based technologies are applied to e-learning systems by providing mechanisms for semantic annotation of learning resources and activities, reuse and combining of course materials, and enabling better searching and navigation [4]. The KPI learning ontology is constructed based on the four concepts *Position, Key Performance Indicator (KPI), Capability, and Knowledge Component (KC)*, with their relations. As outlined in Figure 1, an employee at a *Position* is assessed by a set of *KPIs* required by the organization; to improve the performance relevant to a specific *KPI*, the employee needs

to develop relevant *Capabilities*; to develop a capability, the employee needs to learn relevant knowledge, which can be represented as a number of *KCs*. In addition, recursive relationships between different KCs and different positions are also outlined. For example, one KC can be linked to another KC based on relations such as "part of", "sequential", and "inhibitor"; a position (e.g., junior tester) can be a prior of another position (e.g., senior tester).

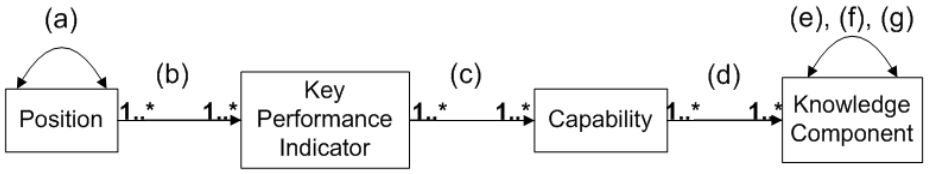

Figure 1. Main concepts with relation cardinalities

3. System Design

Based on the proposed conceptual framework of the performance-oriented approach, we have designed a performance-oriented learning ontology, which lays the foundation for further development of a workplace e-learning system. As it is infeasible to make the design applicable to all company situations, we use the case study approach to investigate the mechanism to operationalize the approach from both an understanding-oriented and an action-oriented perspective. The ontology and system was designed for the Testing Unit of PEANUT SOFTWARE, a selected medium-sized company in Mainland China, which sells and markets technology products including consumer electronics, computing and communication products. There are four departments in the company: Development, Customer Service, Consulting, and Back Office. The Development department consists of two units: R&D and Testing. Testing is an important and mandatory part of software development, clearly essential for evaluating the quality of software products by identifying defects and problems. The design of the system is based on intensive communication with the stakeholders, i.e., software testers, the manager of the Testing unit, the manager of the training sector, and executives in the company.

3.1 Design of KPI-Oriented Learning Ontology

To develop the prototype system, a KPI-oriented learning ontology is constructed for the Testing Unit of the selected company. For performance measurement to be effective, the measures or indicators themselves must be understood, accepted, and owned by employees as well as their managers. Therefore, the building of a KPI-oriented system needs cohesion and integration of different strategies as well as tight cooperation among managers and employees from different units and at different position levels. The construction of the ontology in this study is based on intensive collaboration between the system designers and training managers and experts of the company. Regarding the software testing profession, IEEE standards for software testing introduced in [1] have been used as an important reference for construction of the ontology.

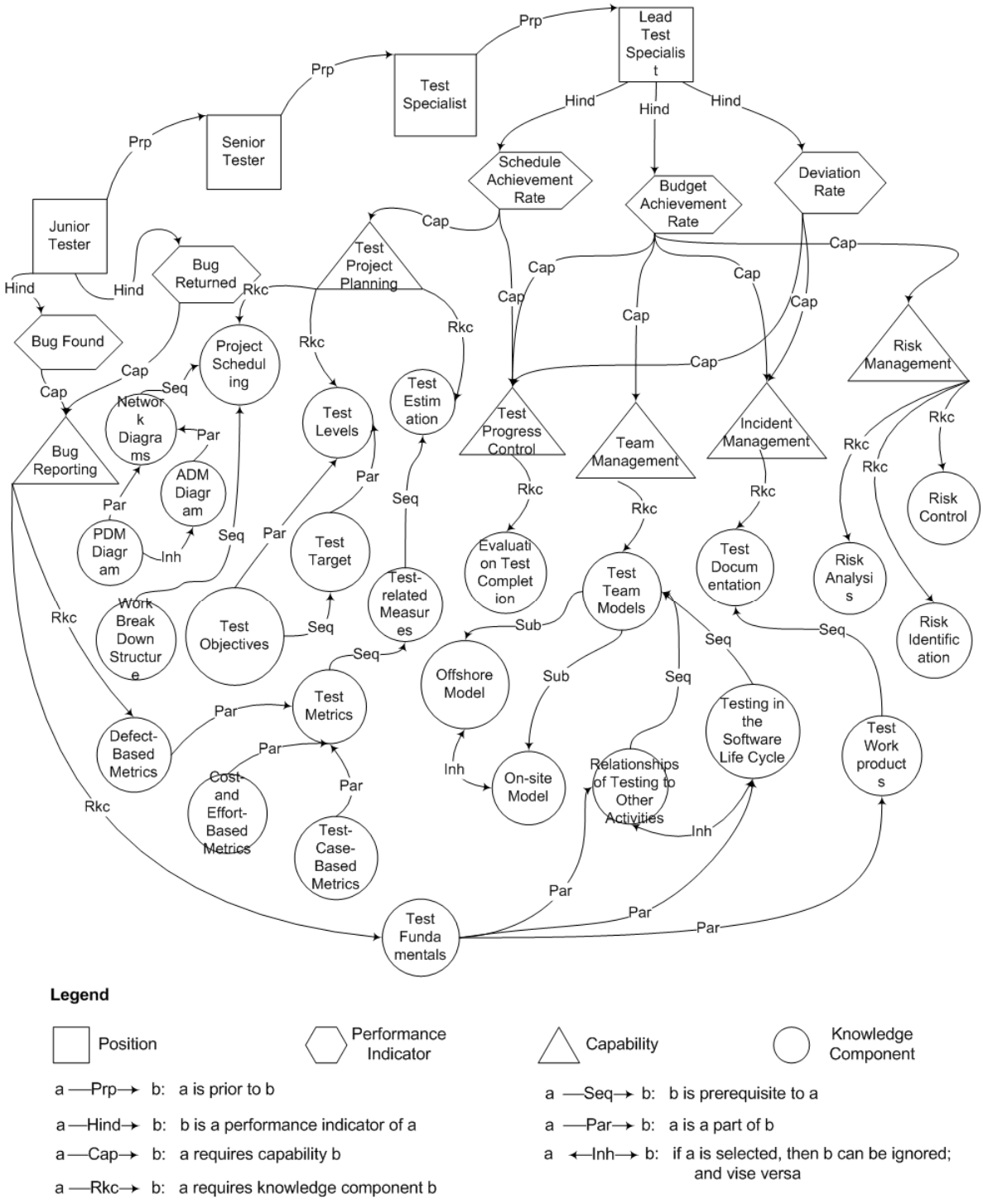

Figure 2. Learning ontology for the Testing Unit

The company defines "Productivity", "Quality", and "Organizational Capacity Construction" as its organizational KPIs. For the Testing Unit, its chief function is to find bugs in software products. Therefore, the Testing Unit defines "Bug Found" as one unit KPI in line with Productivity, "Bug Returned" as another unit KPI in line with "Quality", and "Artifacts Reused"

as the indicator to improve "Organizational Capacity Construction." Based on the defined unit KPIs, the manager and experts of the Testing Unit set KPIs for each position: Junior Tester, Senior Tester, Test Specialist, and Lead Test Specialist. As shown in Figure 2, "Bug Found" and "Bug Returned" are specified as the KPI items for the position Junior Tester. To improve the performance on "Bug Found", the employees need to develop the capabilities including "Bug Reporting" and others. To develop the "Bug Reporting" capability, the employees may need to learn relevant knowledge "Test Fundamentals", "Defect-based Metrics", and so on. The main responsibility of Senior Tester is to design test cases, therefore the corresponding KPI are defined as "Test Coverage" and "Reusable Test Case Rate." In order to improve the performance of "Test Coverage", employees should develop capabilities in "Programming" and "Test Case Design." To improve the capability of "Test Case Design", employees may need to learn the knowledge "Specification-based Design", "Black-box Design", and so forth. Due to the space limitation, Figure 2 presents the details only for Junior Tester and Lead Test Specialist.

Based on the specified KPI framework, each employee is given a set of KPI values for assessment of his/her job performance; to improve the KPI values, each employee may assess his/her knowledge status relevant to his/her position by taking tests or quizzes; based on the test/quiz results, the system will recommend personalized learning resource or activities for the employee. For impartiality and objectivity reasons, the company uses 360 degree feedback to assess employees' performance. An employee's performance can be assessed by performance records from daily work as well as by peer evaluation from the employee him/herself, his/her supervisor, and his/her subordinate or peers. Each appraisal is given a certain weight. As a result, a set of KPI values is calculated to evaluate the employee's work performance.

Based on the ontology specified above, the goal of performance-oriented learning can be achieved by setting up rational learning objectives, accessing relevant knowledge artifacts, and directing individual learning processes through appropriate reasoning mechanism. In addition to the individual learning process, social networking is also facilitated in the learning environment. Learners are able to share and evaluate learning resources, discuss their learning problems or experiences at forums, and conduct peer evaluation of work performance. Each employee is provided with a KPI identification, i.e., a set of KPI values that indicates his/her expertise and proficiency level, stored in the learner's profile. Learners, including domain experts, are able to get familiar with each other based on KPI identifications and contribution to the learning community.

4. System Implementation

To demonstrate the effectiveness of the designed approach, a prototype of the workplace e-learning system has been built up using Java programming tools. We use computational languages and tools to implement the ontology in the e-learning system. OWL-DL (Description Language) is used to define the KPI-based learning ontology. To support the reasoning services, instruction rules are bound with the ontology using DL safe SWRL (Semantic Web Rule Language). To implement both OWL ontology and SWRL rules, we use OWL-API to access Pellet [10] as the semantic reasoning tool.

Moreover, to enable domain experts and training managers to construct and maintain the learning ontology, tools for ontology editing and visualization are necessary. In this study, Protégé together with "SWRL tab" and "Jambalaya tab" plug-in are employed. Protégé is a free open-source ontology editor developed by Stanford Medical Informatics (SMI) at Stanford

University [6]. Protégé holds a library of plug-ins that adds more functionality to the environment. "SWRL tab" is a plug-in for protégé, which provides a SWRL Editor that supports the editing of SWRL rules. "Jambalaya tab" is another plug-in for Protégé to visualize the OWL ontology.

5. Evaluation

The evaluation is focused on the effectiveness of the proposed approach as demonstrated in the developed system. Therefore, we used experiments and comparative analysis for evaluation of this study. Experiments were conducted to compare the developed KPI-oriented e-learning system with another traditional e-learning system without KPI support. Two parallel prototypes were used for evaluation — the KPI-oriented learning system (System A) and another traditional e-learning system without KPI support (System B). System B has similar functions to System A in terms of user management, learning resources, assessment management, and communication tools, but without KPI-oriented facilities. The interfaces of the two systems are also similar to ensure that no design-related factors other than the KPI-oriented facilities affect usage and perception of the systems.

The evaluation examines the effectiveness of an e-learning system developed for a workplace setting, which is different from other e-learning systems developed for educational institutions. Therefore, Donald Kirkpatrick's model [3] was utilized, which evaluates training programs at four levels: reaction (how participants react to the learning system); learning (knowledge learning or skill development by using the application); behavior (transfer of learning into change of behavior by using the system); and result (organizational and individual outcome as a result of the training program).

24 employees who were currently working or had previously worked with the Testing Unit of the company participated in the experiments. The participants were divided into two groups of 12 - the treatment group that used the KPI-based system and the control group that used the traditional system. The data collection process can be divided into four stages. *First*, the participants finished the pre-test. *Second*, after using the system for four weeks, participants completed the post-test and the 1st questionnaire for evaluation of the workplace e-learning system on Reaction, Learning, Behavior, and Result level. *Third*, the two groups were asked to swap systems and use the systems for two weeks; at the end of the stage, the 2nd questionnaire was used to determine participants' preference towards the two prototypes concerning all the aspects of the system. *Finally*, interviews were conducted for qualitative feedback from the participants.

- Results and Findings from the Surveys

Based on the results obtained from the 1st round evaluation, it was found that the KPI-oriented system was perceived to be more effective in terms of meeting individual learning requirement and functional support for learning (Reaction); the KPI-oriented system was perceived to be more helpful to learners in obtaining knowledge and skill (Learning); the KPI-oriented system was perceived to be more helpful in enabling learners to integrate learning into practice and transform individual learning into collaborative learning (Behavior); and the KPI-oriented system was perceived to lead to better outcomes in improving work performance and bringing benefits to the company (Result). On the other hand, the results of the pre-test and post-test scores indicated that there was no significant difference between the two groups in the pre-test or

post-test scores. The results are understandable, as other factors associated with the learners (e.g., their learning capability and effort) as well as their learning environment (e.g., Internet accessibility, speed and cost) may have affected the results.

As a supplement to the 1st round evaluation, the 2nd round evaluation was conducted by swapping the learning systems between the two groups. 20 out of 24 participants completed the 2nd round evaluation. The results of the evaluation, that is, the participants' preference between the two learning systems, is shown in Figure 3. The results show that a majority of the participants preferred the KPI-oriented learning system concerning all the aspects of the system.

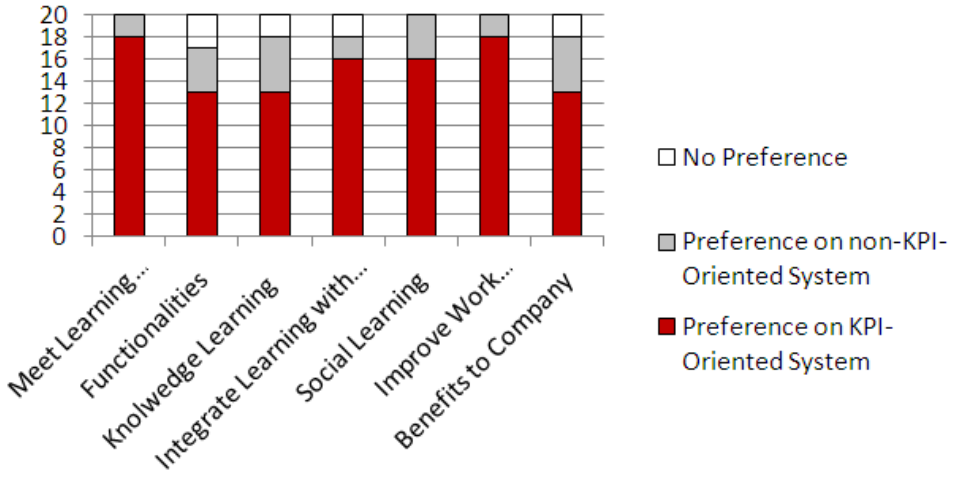

Figure 3. Preference on the learning systems

- Findings from the Interviews

20 participants who finished the experiment and two rounds of questionnaires were interviewed for their feedback on any aspect of the e-learning system. The findings from the interviews showed a more positive evaluation of the KPI-oriented system, especially in terms of providing a clear picture of what needs to be learnt in order to develop specific skills. The learners also gave positive comments about the KPI-oriented system concerning its facilities for effective communications, knowledge sharing, and discussion. As for the training managers, their major concern was cost, which may affect the benefits to the organization from using the learning system. The cost refers to setting up the KPI framework and developing the KPI-based learning system. As a result, the developed e-learning system may not necessarily bring significant benefits to the company in the short term. However, the training managers gave positive comments on the KPI-oriented learning system since they felt that it provided flexible ways of learning and assessment. They also felt that the knowledge contributed by employees can be harnessed and well organized around the KPI model; this may enhance further reuse, aggregation, and sharing of the knowledge asset, and can be regarded as another type of productivity.

6. Conclusion

The main contribution of this work is investigating the mechanism of a performance-oriented e-learning environment by constructing and implementing a KPI-oriented learning ontology. The designed learning ontology has gone beyond learning content by including learning objectives and assessment in line with the KPI framework. The construction of the performance-oriented learning ontology needs shared conceptualization of the stakeholders and professional knowledge from domain experts. The construction of the ontology is also an evolving process where cooperation from designers, employees, training managers, domain experts, and executives is needed in different stages of the project. The results of the study point to the success and benefits offered through ontology technology for developing a performance-oriented e-learning environment in the workplace. It is found that ontology provides a semantic paradigm for designing a performance-oriented learning environment that can operate.

The generalzability of the research findings should be noted that the study was conducted with a software company and within the software testing section, and that the learning ontology designed in this study is only for this specific learning environment. However, the proposed performance-oriented approach implemented with ontology-based technology can be directly applied to other organizational contexts by modifying the content of the ontology.

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