Knowledge portal for Six Sigma DMAIC process

N Thanh Dat¹,², K V Claudiu³, R Zobia⁴ and Lucian Lobont⁵
¹Faculty of Engineering, Lucian Blaga University of Sibiu, Romania
²Faculty of Information Technology, Quy Nhon University, Vietnam
³Faculty of Engineering, Lucian Blaga University of Sibiu, Romania
⁴Department of Computer Science, Comsats Institute of Information Technology, Pakistan
E-mail: ntdat@qnu.edu.vn

Abstract. Knowledge plays a crucial role in success of DMAIC (Define, Measure, Analysis, Improve, and Control) execution. It is therefore necessary to share and renew the knowledge. Yet, one problem arising is how to create a place where knowledge are collected and shared effectively. We believe that Knowledge Portal (KP) is an important solution for the problem. In this article, the works concerning with requirements and functionalities for KP are first reviewed. Afterwards, a procedure with necessary tools to develop and implement a KP for DMAIC (KPD) is proposed. Particularly, KPD is built on the basis of free and open-source content and learning management systems, and Ontology Engineering. In order to structure and store knowledge, tools such as Protégé, OWL, as well as OWL-RDF Parsers are used. A Knowledge Reasoner module is developed in PHP language, ARC2, MySQL and SPARQL endpoint for the purpose of querying and inferring knowledge available from Ontologies. In order to validate the availability of the procedure, a KPD is built with the proposed functionalities and tools. The authors find that the KPD benefits an organization in constructing Web sites by itself with simple steps of implementation and low initial costs. It creates a space of knowledge exchange and supports effectively collecting DMAIC reports as well as sharing knowledge created. The authors' evaluation result shows that DMAIC knowledge is found exactly with a high success rate and a good level of response time of queries.

Keywords: Knowledge Portal, Knowledge Sharing, Ontology, Six Sigma, DMAIC.

1. Introduction
Six Sigma is a customer-focused and data-driven quality strategy [1] used to measure and enhance performance on the basis of collected information and statistical analysis in the field of quality management and process improvement [2]. Through a core Define-Measure-Analyze-Improve-Control process, Six Sigma aims at characterizing and optimizing all defects rates in processes, manufacturing, service or transactional [3] for the purpose of producing 99.9996% defect-free products, and helps an organization enhance business profits and achieve both operational and business excellence [4, 5, 6]. In Six Sigma management, the DMAIC execution is based on statistical and non-statistical tools and techniques to achieve crucial knowledge of processes and products [6]. It creates a favorable environment for managers, experts, employees, customers, and stakeholders to share insights and ideas in improvement solutions with each other. Thereby, valuable knowledge is created in discussion sessions (i.e. Gate Review session) [7], the improvement solutions [8], and brainstorming of the
project participants [9]. However, problem of DMAIC knowledge storage and reuse is one of important challenges for manufacturing processes in organizations.

In recent years, knowledge plays more and more important role in organizations. It enables an organization to achieve efficiencies, ensure competitive advantage, and spur innovation [10] using the brain power of an organization in a systematic and organized manner [11]. Hence, a combination of Six Sigma and KM can enhance quality of products, knowledge created, and organizational performance. Several integrated models of knowledge management and Six Sigma are proposed [12, 13] and [14]. The conventional approach to note in the models is that knowledge is managed in a process of several stages such as creation, capture, organization, storage, dissemination, and application. Nonetheless, problem of developing a unique place of collecting and sharing knowledge is still a task that does not resolved yet completely in recent time.

Many research mention using KP to resolve the problem [15-21]. For example, authors in [15] propose the key components of a KP model, authors in [16, 17] introduce a KP on the basis of commercial web-based application, other researchers depict a framework of KP [18], a KP environment model for facilitating access to relevant information from heterogeneous sources is shown in [19], and two KPs are developed in reality [20, 21].

In [22], we put forward a Knowledge Management model for DMAIC process (i.e. OKMD model). In the model, a KM process involving four steps: reaction/Acquisition, Structure & Storage, Protection, and Application (figure 1) is implemented into each of DMAIC steps. It uses Knowledge Portal as a crucial tool to collect and share knowledge. Yet, developing such Knowledge Portal is one of main challenges in the model. In this article, we try on overcoming the obstacle based on a propose procedure and necessary tools in order to construct the KPD. Our approach is based on free and open-source web-based applications and Ontology Engineering. Although our Knowledge Portal is designed for DMAIC process in Six Sigma projects, it can be applied completely into other manufacturing processes where knowledge is generated. The procedure that introduce how for developing the Knowledge Portal is presented in section 3.2.

In the next section related works are reviewed in order to identify important criterial for such KP as well KPs concerning with KPD. Afterwards, a conceptual model of KPD is proposed on the basis of free open-source web-based applications and Ontology Engineering. A framework of KPD, a procedure and necessary tools for developing KPD, and how to use the tools are included in section 3. Next, our experiments and discussion are depicted in section 4. The last section is to conclude the article.

2. Literature review
The problem of finding tools or solutions for knowledge management in organizations so that knowledge can be accumulated and reused effectively has been getting an attention of researchers. Many researchers believe that KP is one of the best solutions for the problem. Different approaches for various fields are proposed. This sub-session reviews some of the related works.

2.1. Requirements and functionalities for a Knowledge Portal
Identifying requirements and functionalities of a KP are first tasks in KP development. Many studies have shown different ways to determine the requirements in their KP design.

The authors in [23] find the essential specifications of functions in order to develop a KP. Basing on their survey results, the authors believe that a KP’s design should satisfy several requirements such as organizing knowledge repositories, developing collaboration and document sharing tools, creating expertise directory where knowledge workers can communicate with experts, supporting alert and notification, integrating with external contents, and enabling its users to search and retrieve knowledge. The authors also emphasize that knowledge in the KP should be validated by experts in a particular field. In [24], the authors investigate the important degree of specific KP functionalities during the KP design for Research and Development organizations and teams. They note that a KP’s functionalities should be built based on knowledge workers’ task characteristics. Their survey results
show communication, contents and the other important KP functionalities should be considered in KP deployment. Other authors propose KPs for exclusion process services [25] and MSc projects [26]. One of notable features in their research is that the e-learning service plays an important role in their design. It facilitates communication and interaction among its users, enhances the learning experience, and supports planning and monitoring project progress. Furthermore, open source web-based applications is recommended to implement affordable, practical and effective Knowledge Portals [26].

2.2. Related Knowledge Portals

In [15], a Knowledge Portal named “Institute for Advanced Engineering Studies” is built for managing and disseminating implicit and explicit knowledge in academic institutes. The authors of the article have proposed a procedure of four stages involving Content Management, Information Refinement, Information Storage & Retrieval, and Knowledge Dissemination in order to collect and share knowledge. First, knowledge is stored in a Content management module, the domain experts then evaluate the knowledge based on their experience to choose valuable knowledge. Next, knowledge is retrieved in the third stage and to disseminate to the academic users via the stage of Knowledge Dissemination. The authors believe that knowledge can be collected from E-mail, Personal Blog, Conferences, feedbacks, books, journals, reports or any recorded documents. However, this study does not present necessary tools for developing Content Management module as well as techniques for retrieve, structure and store knowledge. Moreover, a discussion on costs and query efficiency for a Knowledge Portal should be included.

Another Knowledge Portal designed for Libraries is introduced by Neubauer and Piguet [16]. The purpose of the authors is to create a “single point of access” in which its users can find electronic information services in a user-friendly presentation format. In order to obtain the purpose, the authors propose a procedure based on a commercial software product named Primo, user-centred process and analysis of actual situation. Their approach enables to organize information packages available and to decide how the information is displayed. The typical users can be participated in interviews for the purpose of describing how they find relevant information. The Primo software is used to create the library’s webpage, and allows its users to find all information they need such as books, e-books, e-articles, digital media and other types of resources. Similarly, the Library Portal of Indian Institute of Technology Bombay for exchanging information and sharing knowledge is introduced by Daulat Jotwani [17]. The Knowledge Portal supports accessing to all its resources and services in order to capture, collect, organize, disseminate and share knowledge and memory of an organization based on supports of information a communication technology (ICT). However, flexibility of customizing the Primo software, the heterogeneity of data, multi-languages for library’s webpage, external users, partners, techniques for integrating external information packages are challenges and risks that should be resolved during the Knowledge Portals deployment.

Markebe Gauvin proposes a knowledge environment framework based on three layers: User, Business, and Data [18]. User layer provides necessary tools for communication, working, task support, specialized tasks and administration. Business layer includes four groups of service: Knowledge, Collaboration, Content Management, and Administration Services. Data layer is organized by applications and content storage for easily accessing, managing and updating its data. The author and the co-authors in [19] also introduce a Knowledge Portal Environment model to facilitate access to relevant information from heterogeneous sources. The authors’ model is based on three main concepts, namely Portfolio, Context, and Ontology to define a user’s or group’s space in which long-term task-oriented activities are fulfilled, to determine the set of all internal or external elements concerning with the activities, and to identify the Ontology-based definitions of the elements, respectively. However, the authors admit that a full deployment of the model results in great challenges regarding to constructing and managing large and complex ontologies, multimedia information resources, legacy systems, users, and security issues.
Other Knowledge Portals for Six Sigma such as SkillSoft [20] or iSixSigma [21] are deployed in reality. They are designed as online e-Learning Center for employees who are currently working or going to work in Six Sigma field. The Knowledge Portals provide its users or learners online document, books and courses in order to enhance their skill level. However, functionalities for such KP are not enough to support knowledge communication, exchange and reuse.

In general, conventional Knowledge Portals support different approaches to share and exchange knowledge for enhancing its users’ skills. However, in most of aforementioned Knowledge Portals, knowledge is not represented in structure, hence it is difficult to be exploited completely by users and inference engines. Furthermore, Knowledge Portals for quality improvement processes such as DMAIC are still not interested to develop yet though it plays an important role in enhancing sustainability of the processes [22]. The costs of deployment as well management for a Knowledge Portal are also challenges. In the next session, we propose a procedure for developing the Knowledge Portal for DMAIC with a low initial costs and affordable and efficient KP functionalities. Our main purpose is to recommend essential steps to a successful deployment as well as necessary tools and techniques in a realizable and simple way. Hence, an organization who is able to deploy Six Sigma projects can develop a Knowledge Portal by itself with an effectiveness of costs and useful functionalities.

3. Knowledge Portal for DMAIC process

3.1. Overview

Knowledge Portal for DMAIC is a unique enterprise website that is designed for a process of knowledge management in OKMD (Ontology-based Knowledge Management for DMAIC) model [22] (figure 1), and combined by functionalities of a Content Management System (CMS), Learning Management System (LMS), and knowledge searching and inferring. The major goal of KPD is to provide its users with useful and necessary functions for collecting, exchanging, storing, reuse and distributing knowledge produced in DMAIC execution.

In this study, KPD is constructed based on open source web-based applications and Ontology Engineering. In order to attain DMAIC knowledge management, our KPD is designed in an architecture of three layers: Interface, Service, and Data layer.

**Interface layer** that provides web-based interfaces to its users, presents content of KPD, and supports user login/authorization.

**Service layer** that provides essential functionalities for content and knowledge management described in figure 2. Basing literature review, functionalities of KPD are grouped into five groups:

- **Content Management:** A group of functionalities for managing organizational information, resources, and links to its customers and employees. This group of functionalities is useful for information and knowledge broadcast of an organization.
- **Knowledge Exchange:** Functionalities for activities of knowledge exchange involving communication and learning, i.e. chat or discussion, organizing online courses and presentation. It also is a place for collecting reports created by Six Sigma tools. During DMAIC execution, each project member can upload his or her reports, discuss with other members, do surveys, and learn or look for Six Sigma knowledge using these functionalities.
- **Knowledge Dissemination:** A group of functionalities that enables to search DMAIC knowledge available for the reuse or evaluation purposes. It simulates Ontologies, provides DMAIC reports
validated, and searches as well as infers knowledge available in the knowledge base based on the Knowledge Reasoner module. A Knowledge Reasoner module is a program that infers logical consequences from a set of explicitly asserted facts or axioms and typically provides automated support for reasoning tasks such as classification, debugging and querying [27].

- **Supporting Document**: Functionalities that provide IT specialists and administrators with materials of IT such as PHP language, Simple Protocol and RDF Query Language (SPARQL), and Apache Jena Fuseki, Protégé, Subtime Text, and ARC2 library in order to construct and develop the Knowledge Reasoner module effectively.

- **Administration**: The functionalities for administrators and IT specialists. They are divided into three sub-groups: User, System, and Configuration Management. Function sub-group of User enables to create and control the security policies of various types of user (i.e. define access permissions of project members, experts, administrators, and IT specialists). System functionalities support activities of system management for servers, databases, and SPARQL endpoint. The last function sub-group allows an organization to create and customize flexibly modules and interface of Web sites by itself.

![Figure 2. The map of functionalities for KPD.](image)

**Data layer** is built as a database in order to store organizational knowledge. In this layer all documents, multimedia files, data of courses, and reports are stored. It is also connected to knowledge bases in which knowledge is created from DMAIC reports and represented by Ontologies. It provides query services based on MySQL and SPARQL.

### 3.2. A procedure for KPD deployment

The deployment of Knowledge Portal for DMAIC is performed based on a procedure of several steps as the follows:

- **Knowledge Portal design**: Basing on KP’s architecture, aforementioned map of functionalities, and organizational demand, an organization defines desired functionalities for its KPD and outline layout of the Web interface.

- **Data collection**: Reports created by DMAIC tools are collected in each Review Session of DMAIC process [7, 14] for constructing and updating Ontologies. Converting the reports to structured file formats (i.e. MS. Excel, structured templates in MS. Word) is necessary.

- **Ontology Building**: Ontologies are used to represent knowledge of DMAIC reports. They are constructed on the basis of classes, properties, restrictions, and relationships. In this step of the procedure, some Ontologies available may be reused.

- **Knowledge Reasoner**: The module for reasoning and querying DMAIC knowledge is developed by using PHP language, created Ontologies, SPARQL query and MySQL, and remoted or local SPARQL Endpoints.
- Integrating and testing Knowledge Reasoner module on KPD. An evaluation is performed based on testing relevant elements designed, on accuracy of reasoning and query results, cost for query time, and costs for developing KPD.
- Portal Implementation: This step of the procedure includes three tasks: (1) register a domain name and hosting (if necessary), (2) install an open source CMS (i.e. NukeViet), LMS (Moodle) and Knowledge Reasoner, and (3) configure system such as layouts, themes, modules, users, user security policies. This step is to ensure that KPD is installed, and its functionalities are configured correctly, and modules are integrated.

3.3. Data collection
In the process of carrying out DMAIC activities, the quality profession and statisticians often apply several tools and techniques for the purpose of improving an existing product, process or service [28]. Each of tools and techniques helps the profession and statisticians to create reports in which new ideas or knowledge are proposed and applied. Hence, in order to manage and reuse knowledge effectively, the reports should be collected. Table 1 depicts some tools and techniques used in DMAIC execution.

| Project phase | Brief Description | Tools and techniques |
|---------------|-------------------|----------------------|
| Define        | Define goals of the improvement activity | Project Charter, Stakeholder Analysis, SIPOC, … |
| Measure       | Measure valid and reliable metrics in the existing system | Preliminary Data Analysis, Initial Sample Results / DPMO… |
| Analyze       | Analyze the system to identify ways to eliminate the gap. | Five Why Root Cause Analysis, Failure Modes and Effects Analysis… |
| Improve       | Improve the system | Solutions Ratings Analysis, Benchmarking Report, Corrective Action Plan… |
| Control       | Control the new system | SPC, FMEA, Best Practices Log… |

![Figure 3](http://www.exinfm.com/six_sigma_project_files.html) (a). DMAIC summary, (b). Stakeholder analysis, (c). Failure Modes and Effects Analysis
Source: [http://www.exinfm.com/six_sigma_project_files.html](http://www.exinfm.com/six_sigma_project_files.html) (b)
[http://www.isixsigma.com/tools-templates/fmea/process-diagram-fmea-help-prepare-utility-disaster/](http://www.isixsigma.com/tools-templates/fmea/process-diagram-fmea-help-prepare-utility-disaster/) (c)

However, the DMAIC reports are often produced in text-based document format, some of them are in structured format (i.e. tables), and others are unstructured documents. Hence, in this step of our procedure converting all reports to the unique structured templates is necessary. The structured reports are then entered into computers using text editing software such as MS. Word, MS. Excel. figure 3 shows three type of reports structured.
3.4. Ontology-based knowledge representation

In the field of Artificial Intelligence, knowledge representation is to aim at designing computer systems that reason about a machine-interpretable representation of the interest domain, similar to human reasoning [29]. Basically, knowledge can be represented by one of three methods that is either Document, Taxonomy/Ontology, or Artificial Intelligence [30]. Ontology-based knowledge representation supports both implicit and explicit knowledge by defining set of concepts and their relationships. Moreover, the method supports a knowledge share among human, different applications, and computer systems [31].

In our KPD, DMAIC knowledge is represented by a semantic network or graph (Ontology) in which nodes describe concepts, and their arcs depict relations between these concepts [29]. Thereby, an Ontology is a structural representation of statements about a domain of interest. It includes classes (concepts), properties, instances, and constraints. There are two types of properties: Object-type property and Data-type property. Object-type property links a class to a class, Data-type property links a class to a value (i.e. string, number, date…).

Simply, a DMAIC report is structured into columns, rows, and values of a table. The table is then translated into a sub-network or a branch of Ontology graph. Each row name of the table is translated into an instance name. Each column name can be translated into either a class name or a name of Data-type property. A value (a cell in the table) is mapped to a value of a Data-type property. Each property describes a relation from a class to a class, or from a class to a value. Thereby, a structural report can be translated into an Ontology. For example, a report of DMAIC brief summary (figure 3.a) is translated into an Ontology in which each column name (i.e. Problem, Voice of the customer, Scope…) is translated into a name of data-type property (i.e. problem_desc, customer_voice, define_scope in figure 4), each row name is translated into an instance name. Each value is translated into a value of data-type property. Each class may have some its sub-classes (i.e. Define, Measure, Analyze, Improve and Control are sub-classes of class DMAIC_process). Figure 4 presents knowledge representation of DMAIC brief summary and FMEA report into an Ontology.

![Figure 4. An Ontology sample for DMAIC Knowledge in Protégé VOWL view.](image)

However, in order to support knowledge inference, Ontology schema should be analyzed carefully so that all knowledge can be inferred completely. Depending on structure and content of DMAIC reports, various Ontologies can be built to represent knowledge of the reports. Moreover, updating an Ontology can be performed manually or based on an OWL-RDF Parser, which is responsible for adding/inserting data (triples) from a report (RDF/XML/XLS file) to an Ontology.

Many Ontology Editors such as Apollo, OntoStudio, Protégé, Swoop and TopBraid Composer Free Edition support constructing and editing Ontology. In our study, knowledge representation should be performed by Protégé Ontology Editor because it is a free open-source platform and provides its users necessary tools to construct domain models and knowledge-based application effectively [32]. It
supports database storage that is scalable to several million concepts, useful plug-ins and reasoning tools, intuitive user interface, Ontology Web Language (OWL) files, and SPARQL. A guideline for building an Ontology can be done as recommended in [33, 34].

3.5. Developing Knowledge Reasoner module

In order to search and infer DMAIC knowledge, a Knowledge Reasoner (K-Reasoner) module is developed. It is written in PHP language and SPARQL. Its algorithm consists of functions that enable to get and analyze query requirements, to connect to Ontologies through SPARQL endpoint, to generate and perform SPARQL queries, and to present query results found. Moreover, this module supports various types of search such as Quick Search, Basic Search, Advanced Search, and Question-based Search (figure 5.a). A User of KPD can choose one of searching types to submit his or her keywords or a question, and then receive a result in various ways of displayed forms.

SPARQL is a SQL-like language for querying RDF data such as Ontologies. It uses an expression of RDF graph in WHERE clause to look for a relevant result that matches with the query. Therefore, it supports various query result forms to return the list of values of variables bound in a query pattern, RDF graphs, or Yes/No answers. Figure 5.b illustrates a part of PHP code for creating SPARQL query in K-Reasoner module.

![Figure 5. (a) Architecture and (b) a partial PHP code of K-Reasoner module.](image)

SPARQL endpoint is an access point for SPARQL queries for collecting semantically structured data [35]. It allows querying knowledge from a knowledge base through SPARQL language. Several tools support constructing a SPARQL endpoint involving Virtuoso, Sesame, and Jena/Joseki. However, deployment of SPARQL endpoint is often complex and expensive. Hence, a local triple store can be deployed on the basis of PHP and ARC2 library instead of a SPARQL endpoint. ARC2 library provides functions to execute SPARQL queries easily using MySQL although the searching time for a query may be longer.

3.6. Deployment of CMS and LMS

A Content Management System (CMS) is defined as an open source web-based software application for managing and delivering content of a Web site. It enables the content managers or authors, who may not know HTML, XML, PHP, or web programing languages to easily create, edit, archive, censor, publish, collaborate on, report, and distribute articles, events, statistical data, and other information. Links to external resources such as social networks, libraries, and other websites as well as many types of resources such as video, image, and file are managed easily. It is designed for multiple users with different permission levels, and for different sections of administration. Many open source CMSs such as NukeViet, WordPress, Drupal, Joomla, and Pimcore allows an organization to construct freely its own websites or online applications.
Also, open source Web-based software applications such as Moodle, Dokeos, Blackboard, Sakai, Latitude, and Schoology are Learning Management Systems (LMSs) that allow to administrate, document, track, report and deliver e-learning courses or training programs. LMS supports completely planning, implementing, assessing a specific learning process, and facilitates accessing the process. It provides its users with the ability to use interactive functionalities such as online discussion, conference, forum, and chat. Thereby, an organization can use LMS in order to enhance and support its teaching and learning activities. Moreover, the communication tools and learning provided by a LMS enable processes of knowledge conversion in Nonaka’s model [36] to be carried out easily. Using courses and tools facilitates exchange between tacit knowledge and explicit knowledge. Hence, the process of knowledge creation is deployed more easily. Communication tools are helpful to use in Gate Review sessions where discussion is organized by members of a Six Sigma project.

Thereby, a knowledge worker can access and convert knowledge available in many ways through CMS (i.e. social networks (Facebook, Google+), and YouTube), LMS (usage of communication tools and courses), and Knowledge Reasoner module (for accessing DMAIC knowledge created).

Some hosting providers support a One-click service in which open source web-based applications are available and installed automatically. Installation guide for NukeViet and Moodle are found in [37] [38]. KPD’s functionalities are installed and customized correspondently to the Knowledge Portal design.

3.7. Supporting Document
This function provides document concerning with KPD deployment for IT specialists who administrate and develop KPD in an organization. It helps KPD implementation to be uninterrupted by a change of IT personnel of the organization. Document for Web programing language (PHP, JavaScript, HTML, Sublime text, ARC2...), Ontology (Protégé, RDF, XML...), query languages (SPARQL, SPARQL Endpoint, MySQL...) and other technical document (NukeViet, Moodle, system configuration, K-Reasoner module...) are included.

4. Experiment and Discussion
In order to validate the proposed procedure, we build a KPD that on the basis of the proposed implementation steps and supporting tools with the following parameters:

- Domain and hosting provider: DreamHost; at https://dreamhost.com; costs: $95.4 per year.
- Content management system: NukeViet, version 4.0.23, downloaded at https://nukeviet.vn/en/
- Learning management system: Moodle, version 3.0.2, at https://download.moodle.org/
- Tools for building local PHP hosting: Xampp version 3.2.2 (for PHP server & MySQL)
- Tools for build SPARQL Endpoint (Local & PHP + MySQL): Apache Jena Fuseki 3.0.1, ARC2.
- A FMEA ontology is reused for evaluating the Knowledge Reasoner module.

In the first step of the procedure, NukeViet and Moodle are used to integrate with KPD because their useful functionalities. NukeViet or Joomla are open source web-based applications providing necessary functionalities to build Web sites and powerful online applications [39] [37]. NukeViet supports a good organization of information resources, links, easy installation, flexible customization of Web interface, automatic setup modules and themes, and multi-interface language as well as multi-database language. Besides, Moodle enables to create an online space of various types of communication, to organize effectively courses. Thereby, it is one of best LMSs for developing an environment of knowledge exchange. Both NukeViet and Moodle use PHP language and MySQL, hence fore-knowledge of the languages is necessary developing the applications. Both supports module-based customizable management features and statistical reporting functionalities. Hence, a combination of CMS and LMS helps an organization for managing and organizing its knowledge efficiently and effectively.
In our experiment, the sources of NukeViet and Moodle are uploaded to our Dreamhost hosting. After a process of installing and creating databases, the groups of functionalities are configured on the basis of the functionality maps for KPD (figure 6).

The functionalities of Content management for KPD is developed based on NukeViet. We find that NukeViet provides a News module that enables to create, edit, and delete articles related to organizational information such as Six Sigma project information, solutions, innovations, and events in hierarchical categories. The articles can be distributed to various types of web users based on their own permission, and attached by several types of resources such as video, image, file, and link. Thereby, a knowledge worker can access relevant information and resources on the basis of a company’s security policy. The module is used to create blocks that display the articles in various web-based presentations. In order to provide web users with resources, links, and document repository (for Supporting Document function), some new modules available on NukeViet’s website are also installed. The most interesting feature to note is that all web pages are customized easily based on the operations of drag and drop. Hence, KPD’s web-based interface are organized by blocks that can be added, moved, or deleted quickly by any administrator or even a person is not be an IT specialist. The last but not least, the icons of linking to social networks such as Facebook, Google+, and YouTube are located at the top-right corner in all web pages of KPD. Thereby, KPD is connected to various knowledge resources for the purpose of providing its users (i.e. members of Six Sigma project, or experts) with more knowledge available. As a result, the function group of Content management of KPD is developed and displayed a flexibly customized layout.

![Figure 6. (a) Homepage and (b) Knowledge Exchange sites of KPD.](image_url)

A space of knowledge exchange for KPD including activities of learning and communication is built by using Moodle. A course for members of a Six Sigma project can be created in one of four formats: Single activity, Social, Topic, and Weekly. Two popular formats of course are used to create Six Sigma courses are Topic and Weekly formats. A teacher can organize a course in several sections (topic names or weeks) with several learning activities such as assignment, chat, choice, feedback, forum, lesson, SCORM (for presentation). The teacher can send materials and assignment to, or collect reports from learners, as well as create surveys, questionnaire, or tests. Single activity format supports a teacher to create only one of mentioned learning activities. Social activity format create a space of discussion such as a forum. Maybe it is not a full course, which includes several activities for learning, but if a course is organized as a discussion session (i.e. Gate Review sessions in DMAIC process), then the format is a suitable choose. As figure 6.b depicted, the courses and communication tools are created for Six Sigma project training. A member of Six Sigma project can join into desired courses. Online Gate Review sessions in each of DMAIC steps can be organized using Knowledge Exchange portal.
Another important component developed in our experiment is Knowledge Reasoner module. The module is developed on the basis of the architecture in figure 5.a. First of all, XAMPP software, which is a free and open-source web platform, is installed in order to execute Apache web server service and MySQL database server. Next, a searching form (figure 7.a), which gets user requirement in keywords or a question, is written in PHP language. The keywords are used and analyzed to generate a SPARQL query. In order to carry out the SPARQL query and evaluate searching efficiency and costs, both SPARQL endpoint and a local triple store are deployed. Finally, the query result is presented as figure 7.b.

In this experiment, searching efficiency and costs are evaluated based on the successful rate and response time of queries. To do this, an Ontology built from FMEA reports (figure 3.c) is reused. The processes in FMEA reports are translated into the 8 classes, 37 properties and 1,758 individuals of the Ontology that is formed by 9,279 RDF triples. Advanced knowledge search form (figure 7.a) is used to send a query requirement to the Knowledge Reasoner module in order to list all FMEA processes in the Ontology. The searching result is presented in figure 7.b. The experiment is carried out based on two types of SPARQL server: Apache Jena Fuseki, and MySQL+ARC2 for the purpose of evaluating the response time of the query.

One of the most striking points to evaluate Knowledge Reasoner module is successful rate of queries. According to figure 7.b, the total of processes found by the module is 414 processes, with successful rate reaching 100 per cent. This shows the reliability of the module in querying DMAIC knowledge from Ontology. Another notable feature is the response time of the queries, the maximum response time of a query using Fuseki server is smaller than that using MySQL server, 0.75 seconds and 4.61 seconds respectively (figure 8).
Hence, Fuseki serves SPARQL queries much better than MySQL. However, the costs for Fuseki deployment is more expensive than MySQL, $239.4 and $95.4 respectively. Therefore, usage of MySQL server is suitable for small knowledge bases while Fuseki is an intelligent choice for bigger knowledge bases with many Ontologies and tens of thousands RDF triples.

5. Conclusion
This article has presented a procedure to develop a Knowledge Portal for DMAIC processes in Six Sigma projects. Our proposed procedure involves description of implementation steps, supporting tools, necessary functions, techniques for constructing Ontologies and searching knowledge. Although the initial costs for developing the Knowledge Portal is often high, using open source systems enables an organization to decrease considerably the costs and also support to flexibly customize its components. Ontology Engineering enables to store knowledge found in DMAIC reports in Ontologies, and hence inferring the knowledge for the purpose of reuse. Moreover, KPD also supports an organization to broadcast organizational information and create a knowledge exchange space for its employees and customers. The result of experiment shows that our procedure is availability and realizability. KPD is constructed completely based on the procedure. Knowledge created during DMAIC execution is collected and shared efficiently, search costs is acceptable. We also consider that the success of KPD depends not only on building the Portal but also on the contribution of participants [40]. Moreover, for future works, some challenges should be resolved for KPD involving (1) an evaluation for KPD fulfilled by businesses who are able to deploy Six Sigma projects in reality, (2) the problem of combing multiple Ontologies, (3) answering questions in natural language.

Acknowledgement
This article has been done within Doctoral studies under the financial support of Erasmus Mundus Mobility with Asia (EMMA). Authors are very much thankful to the EMMA management team for their support.

References
[1] Lin C, Chen F F , Wan H –d , Chen Y M and Kuriger G 2013 Continuous improvement of knowledge management systems using Six Sigma methodology Robotics and Computer- Integrated Manufacturing 29(3) pp 95-103
[2] Jirasukprasert P, Garza-Reyes J A, Kumar V and Lim M K 2014 A Six Sigma and DMAIC application for the reduction of defects in a rubber gloves manufacturing process International Journal of Lean Six Sigma 5(1) pp 2-21
[3] Antony J 2007 What is the role of academic institutions for the future development of Six Sigma? International Journal of Productivity and Performance Management pp 107-110
[4] Yang K 2005 Design for Six Sigma for Service (New York: McGraw Hill)
[5] Pande P, Neuman R and Cavanagh R 2000 The six sigma way team field book (New York: McGraw Hill)
[6] Chuni W and Chinho L 2009 Case study of knowledge creation facilitated by Six Sigma International Journal of Quality & Reliability Management
[7] Stevens D E 2006 The leveraging effects of knowledge management concepts in the deployment of six sigma in a health care PhD Thesis (Walden University: USA)
[8] Tracy Zou X and Lee W 2010 A study of knowledge flow in Six Sigma teams in a Chinese manufacturing enterprise The Journal of information and knowledge management systems pp 390-403 [9] Javier Llorëns-Montes F and Luis M 2006 Six Sigma and management theory: processes, content and effectiveness Total Quality Management and Business Excellence
[10] Opresan C, Kifor C V, Negulescu S C and Bârbat B E 2009 Innovating Engineering Education, to Face the Knowledge Society Proc. of the Balkan Region Conference on Engineering and Business Education & Int. Conf. on Engineering and Business Education (Sibiu)
[11] Andreea M 2002 Overview of Knowledge Management New Directions for Institutional Research
[12] Yeung R 2004 Integrating Six Sigma with Knowledge Management, Available at: www. six sigma.org.hk
[13] Nold III H 2011 Merging Knowledge Creation Theory with the Six-Sigma Model for Improving Organizations: The Continuous Loop Model International Journal of Management p 469
[14] Kifor C V and Baral L M 2013 An Integrated DMAIC-Knowledge Management Conceptual Model for Six Sigma Quality Management International Conference on Manufacturing Science and Education-Mse (Sibiu)
[15] Das S and Sudipta B 2014 Knowledge Management in Academic Institution through Knowledge Portal Trends in Management of Academic Libraries in Digital Environment
[16] Neubauer W and Arlette P 2009 The Knowledge Portal, or, the Vision of Easy Access to Information Library Hi Tech 27(4) pp 594-601
[17] Jotwani D 2005 Library Portal : A Knowledge Management Tool INFLIBNET Centre
[18] Gauvin M, Boury-Brisset A-C and Garnier Waddell F 2002 Contextual User-Centric, Mission-Oriented Knowledge Portal: Principles, Framework and Illustration 7th International Command and Control Research Technology Symposium (Quebec City)
[19] Marlene G, Boury-Brisset A–C and Auger A 2004 Context, ontology and portfolio: Key concepts for a situational awareness knowledge portal Proceedings of the 37th Annual Hawaii International Conference on. IEEE (Hawaii: System Sciences)
[20] Skillsoft® Six Sigma Knowledge Center™ Skillsoft, 1998. [Online]. Available: http://www.skillsoft.com. [Accessed 2016].
[21] "iSixSigma," [Online]. Available: http://www.isixsigma.com/.
[22] Nguyen T D and Kifor V C 2015 The Sustainability in a Quality Improvement Model Balkan Region Conference on Engineering and Business Education (Sibiu: Romania) 1(1)
[23] Zaihisma C C, Hidayah S, Wan M I and W M W M I 2015 Islamic knowledge portal: An analysis on knowledge portal requirements Journal of Engineering and Applied Sciences 10(2) pp 451-456
[24] Lee H J, Jong W K and Joon K 2009 A contingent approach on knowledge portal design for R&D teams: Relative importance of knowledge portal functionalities Expert Systems with Applications 36(2) pp 3662-3670
[25] Krzysztof H, Mieczyslaw L O and Maciej P 2014 Knowledge portal for exclusion process services Computer Science and Information Systems (FedCSIS)
[26] Munive-Hernandez J E 2011 Implementation of a knowledge portal as an e-learning tool to support MSc projects Proceedings of the 11th International Conference on Knowledge Management and Knowledge Technologies
[27] Kathrin D, Ronald C, Annette T and Nicolette D K 2011 Comparison of reasoners for large ontologies in the OWL 2 EL profile Semantic Web 2(2) pp 71-87
[28] Thomas P 2003 The Six Sigma Handbook. A Complete Guide for Green Belts, Black Belts, and Managers at All Levels (New York: McGraw-Hill)
[29] Stephan G, Pascal H and Andreas A 2007 Knowledge Representation and Ontologies Logic, Ontologies and Semantic Web Languages CiteSeerX
[30] Ribino P, Oliveri A, Lo Re G and Gaglio S 2009 A Knowledge Management System based on Ontologies New Trends in Information and Service Science
[31] Benjamins V, Fensel D and Gomez Perez A 1998 Knowledge Management through Ontologies Practical Aspects of Knowledge Management (PAKM98) (Switzerland)
[32] Emhimed A 2013 Comparison Some of Ontology Editors Management Information Systems 8(2) pp 018-024
[33] Natalya F N and Deborah L M 2001 Ontology Development 101: A Guide to Creating Your First Ontology pp 1–25
[34] Horridge M, Jupp S, Moulton G, Rector A, Stevens R and Wroe C 2009 *A Practical Guide To Building OWL Ontologies Using Protégé 4 and CO-ODE Tools* Edition 1, 2 (The University of Manchester)

[35] Zviedris M and Guntis B 2011 ViziQuer: a tool to explore and query SPARQL endpoints *The Semantic Web: Research and Applications* (Springer: Berlin Heidelberg)

[36] Nonaka I and Konno N 1998 The concept of ‘ba’: building a foundation for knowledge creation *Knowledge management: critical perspectives on business and management* pp 40-5

[37] "NUKEVIET CMS," VINADES, JSC, [Online]. Available: https://nukeviet.vn/en/. [Accessed 26 02 2016].

[38] Rice W H and William H 2006 Moodle. E-Learning Course Development. A complete guide to successful learning using Moodle

[39] Nguyen L U 2013 Networks at their Limits: Software, Similarity, and Continuity in Vietnam *eScholarship* (Los Angeles)

[40] Loebbecke C and Kevin C 2012 Knowledge Portals: Components, Functionalities, and Deployment Challenges *International Conference on Information Systems* (Orlando: FL)