Designing an Open Virtual Factory of Small and Medium-sized Enterprises for Industrial Engineering Education

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ABSTRACT
Curriculum of Industrial Engineering program must accomplish the requirement that graduates have the ability to design, develop, implement, and improve integrated system that include people, materials, equipment and energy. However, it is not easy to implement a curriculum that fosters such competencies. One of the strategies to achieve that is using an innovative learning media, so that the problem-based learning (PBL) can be accustomed. In this paper, we design a web-based enterprise resources planning. It is aimed to capture the real problem of small and medium-sized enterprises (SMEs) in bottled drinking water industries. The integrated system can be illustrated as ERP application that designed by using free open source software (FOSS). This research aimed to utilize the application to improve teaching methods in IE education. The result of the research can be used to improve the competencies of IE students, especially the abilities to identify, formulate, and solve the activities of the business process improvement in SMEs.

Keywords
Industrial engineering education, FOSS, innovative learning media, problem-based learning

1. INTRODUCTION
The Accreditation Board for Engineering and Technology (ABET) determine criteria for accrediting Engineering Programs [1], [2]. Program criteria for Industrial Engineering (IE) must accomplish the requirement that graduates have the ability to design, develop, implement, and improve integrated system that include people, materials, equipment and energy [2]. To comply with the ABET engineering criteria, a program must formulate program educational objectives and formulate a set of program outcomes [3], [4]. The program must include in-depth instruction to accomplish the integration of system using appropriate analytical, computational, and experimental practices [2]-[3]. One important instrument for matching the ABET engineering criteria is the program curriculum, that consist of course syllabi, learning objectives, teaching materials/course notes and assessment methods to address the program outcomes.

The IE curriculum designated to address the knowledge, skills, and attitudes specified in the student outcomes. It is required three main activities (planning, instruction and assessment & evaluation) for designing the program curriculum [4]. One of them, the planning activity is for identifying course content and defining measurable learning objectives for it. Furthermore, the problem-based learning (PBL) is teaching method to present realistic and relevant problems of integrated system and to contemplate approaches for solving them [4], [5]. The characteristics of PBL are: a student-centered learning is driven by challenging, draws on essentially constructivist principles of learning, students work in small collaborative groups; and lecturer as facilitators [5], [10], [13]. However, it is not easy to implement a PBL curriculum that fosters such IE competencies.

On the other hand, a learning tool is a tool to deliver the message of learning [6]. A good learning tool or teaching media can activate learner in analytical, computational, and experimental practices of a course [7], [8], [9], [12]. One of strategies to foster the student outcomes is by using an innovative teaching media, so that the PBL can be accustomed. Media-based instruction methods have the ability to dramatically increase efficiency in the classroom and capture students' attention [7], [9], [10], [11]. In the last few years, there are several models available regarding this issue [7], [8], [12], [14]. In fact, a lecturer still faces problems for implementing such methods.

An effective media-based instruction method has to develop to align with IE’s curriculum with PBL system in each of IE program. In this paper, we can use FOSS to design an innovative learning media as an Open Virtual Factory. We design to line up it between PBL system and IE’s curriculum in IE department, Sebelas Maret University. The real problem of small and medium-sized enterprises (SMEs) in bottled drinking water factory is proposed for illustrating realistic and relevant problems. We design a web-based enterprise resource planning (ERP application) to capture the virtual integrated system. This study aimed to design an Open Virtual Factory of SMEs for teaching IE Courses in IE Department, Sebelas Maret University.

This paper is organized as follows. In Section 1, we propose the background of our research. In Section 2, we provide the literature reviews to resume the PBL system and the previously learning media models. In Section 3, we provide the methodology for solving the problem. In Section 4, we design the Open Virtual Factory. We introduce a user guide to use learning media for teaching IE courses in Section 5. Section 6 summarizes and concludes.
2. THE INDUSTRIAL ENGINEERING EDUCATION

Department of Industrial Engineering (IE) Sebelas Maret University (IE-UNS) established in 1998. Now, the IE-UNS apply third generation on the development of curriculum (2008-2013). The IE-UNS offers undergraduate program study leading to the Bachelor of Science degree (S.T.) [15]. The curriculum, which is built upon a strong background in mathematics and the physical and engineering sciences that are common to all engineering disciplines, coupled with specialized study in subject areas such as such as optimization, probability and statistics, computing, economics, and psychology. There must be at least 144 hours of courses. The IE-UNS curriculum is designed to prepare students to become effective industrial engineers by enhancing their technical expertise and exposing them to critical issues of manufacturing system practice. IE graduates are well suited to solve modern management problems, using sophisticated quantitative analysis, and dealing with highly technical issues [16].

A good learning tool can give students a much better picture in analytical, computational, and experimental practices of a course [17]. It is require a complex ability for teaching IE subjects. For supporting the teaching IE subjects, it is necessary to provide industrial experience to allow students to enhance their learning of the courses and practice engineering problem solving skills. In the study of IE subjects, presently a change of learning and teaching happens through the use of new media.

There are many students who prefer to play computer games than study, and this provides the 'fun factor' from interactive computer games while still being a vehicle to facilitate course-specific learning [7]. For this reason, it is important to design "virtual factory" for illustrating the critical issues of manufacturing system. The virtual factory as virtual teaching media is the general term for networks of virtual models and methods based on simulation [14]. In the virtual labs construction, it is necessary to see four basic areas: resource preparation, communication with student, examination, and organizational part [9]. There are several models of virtual labs, for instant LearNet (learning and experimenting on real technical plants, www.learnet.de); Learn2Control (project oriented multimedia learn environment for control engineering, www.learn2control.de); and the international projects are IECAT (Innovative Educational Concept for Autonomous and Teleoperated Systems, http://www.ars.fh-weingarten.de/iecat).

3. RESEARCH METHODOLOGY

We proposed an Open Virtual Factory of SMEs for teaching IE Courses IE Department, Sebelas Maret University. The phenomenon problem was solved using four stages as shown in Fig. 1.

- We simplify the real system of SMEs to illustrate the integrated system then map the business process references to capture inter-relation between each department. They are production, logistics, marketing, and finance.
- We improve the application from previously research [20], [21] especially the DBMS and the user Interface. The ERP web-based was created for illustrating the Open Virtual Factory.

- The application created by using Web Service Definition Language (WSDL), object oriented programming method with PHP, MySQL, and Simple Object Access Protocol (SOAP).
- Then, we create the media-based instruction, which is a user guide to use learning media for teaching IE courses.

| Analyze the business process in a small-mid size SMEs bottled drinking water [21]. |
| The business process mapping |
| 1. Simplifying the real system of SMEs to illustrate the integrated system |
| 2. Mapping the business process references to capture inter-relation between each departments |
| The Development of an ERP Web-based as Open Virtual Factory |
| Improve the application from previously research [22], [23]: |
| - to improve the DBMS |
| - to improve the user Interface |
| The Media-based Instruction Method |
| (It discusses a user guide to use learning media for teaching IE courses) |

Figure 1. The development of an Open Virtual Factory as a Learning Media

4. THE BUSINESS PROCESS MAPPING

Bottled water or any term of similar import means water obtained from an approved source which is packaged for sale or distribution. Drinking water means bottled water which has been distilled, fluoridated or purified or which has been disinfected by a process of ozonation and filtration or any substantially similar disinfection process [18].

The real business process of small and medium-sized enterprises (SMEs) in bottled drinking water factory is mapped by [19]. Bottled water is produced using seven stages as shown in Fig. 2. Stage P1 is source of water obtained from artesian well water or well water. The distillation and disinfection activities are processed at stage P2 to P6. Stage P7 is filling water into cup (250 ml); bottles (600 ml and 1500 ml); and gallon.

Figure 2. A process of distillation in SMEs

We refer to [21] as business process standard in Virtual Factory of SMEs (Fig. 3). The business processes begin production
considering sales data, production planning, and inventory. We organize all activities into four departments which is production, logistic, marketing and finance (Fig. 4). The Production department is to organize the relationship production-supplier; production-logistic; and production-finance. The logistics department is to organize the relationship logistic-supplier; logistic-production; and logistic-finance; logistic– marketing and logistic-distributor. The marketing department is to organize the relationship marketing-distributor, marketing finance and marketing-logistic. The finance departments is the relationship finance-distributor, finance-marketing, finance-logistic and finance-production. To support the business processes improvement well, it was necessary to design an information system [20].

Figure 3. The Business Process Standard In Virtual Factory
5. THE DEVELOPMENT OF AN OPEN VIRTUAL FACTORY

We improve the application from previously researches [20],[21] to customize the DBMS and the user-interfaces. First, we design the proposed system consist of 3 steps as follow: physical design, logical design and context diagram. The physical design shows the structure of ERP menus. The logical design is pictured using data flow diagram. And, the context diagram used to depict the application flows when the application is evaluated by process and performance views.

We use RDBMS (Relational Database Management System) concept to support the business processes. This concept chosen because it is familiar to software developers and there are many application exist, include open source applications. Based on the DFD developed of each module, we design tables needed in database and after normalization process (24 tables).

The web interfaces developed using free open source software which is WSDL, an Object Oriented package program module of PHP, MySQL, and Simple Object Access Protocol (SOAP). The WSDL interface was used to communicate information between different platforms that owned by each entity in the application through the HTTP protocol. PHP was used as web programming and MySQL was used as relational database structure. The layer of application has five layers as follow: web application, SOAP server, WSDL, database and operating system. The Open Virtual Factory application is implemented by two sides, that is the client side and the server side (Fig. 5).

User interface is designed to ease user to interact with the information system. The user interface is written in Indonesian language, because the users are Indonesian. Fig. 6 shows the hierarchy of menu of the user interface. The user interfaces designed are 4 forms for master data and 6 forms for transaction data; 4 documents and 5 reports. The outputs of user interface are in monitor screen and in printer. Figure 7 is an example of the user interface designed.

![Diagram of the coordination inter-department in SMEs](image)

**Figure 4. The coordination inter-department in SMEs**

![Architecture diagram of the Open Virtual Factory](image)

**Figure 5. The architecture of the Open Virtual Factory**

6. THE MEDIA-BASED INSTRUCTION METHOD

For implementing proposed learning media, we should propose instruction method. The media-based instruction method is a system that provides an instructor with tools to create and deliver content, monitor student participation and assess student performance the three stages are needed to design it as follows:

- the simple help guides for the system
- a repository for virtual learning materials and learner tracking
- the guidance for lecturer and students.

The hardware requirement for implementing this teaching media is as follows:

- a personal computer for server with recommended specifications: processor Intel dual core 2,4 GHz, RAM 2Ghz, and Hard disk 40Gb SCSI.
- Database server with minimum specification IBM Server, RAM 8Ghz, and Hard disk 240Gb SATA.
Figure 6. The hierarchy of menu of the user interface

Figure 7. User Interface sample of marketing module
CONCLUSION
We have introduced the open virtual factory of SMEs to give an example of real problems for IE education. Consider of the PBL system and IE’s curriculum is important things to get the innovative learning media for teaching IE Courses. The ERP web-based was created for illustrating the Open Virtual Factory by using WSDL, PHP and MySQL. The PBL system using the Open Virtual Factory involves students learning through engagement with problems, rather than being learned with the conventional lecture-tutorial approaches. The proposed system would improve students’ learning experience, especially for identifying the real problems in the bottled drinking water enterprise. The IE students can enhance their understanding of the subject matter. Furthermore, they can exercise to design, develop, implement, and improve the integrated system by elaborating the real problems in the open virtual SMEs.

This paper has certain limitations that should be overcome in order to provide in deep analysis. For further research, this result could be extended by further investigation as follow the testing method to evaluate prototype and the experiment method to assess the student’s performance. As any other open source application, this application invites people around the world to complete the model.

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8. REFERENCES

