International Journal of Engineering Education Vol. 32, No. 5(B), pp. 2229–2239, 2016
Printed in Great Britain
0949-149X/91 $3.00+0.00

Capstone Course Support System with Knowledge Acquisition and Utilization for Participant-directed Learning*

MOON-SOO KIM
Department of Industrial &Management Engineering, Hankuk University of Foreign Studies (HUFS), Yongin City, Republic of Korea.
E-mail: kms@hufs.ac.kr

The capstone course in colleges of engineering is participant-directed learning (PDL) based on project-based learning (PBL) and is one of the most important courses for students aiming to become competent professional engineers capable of solving real industrial problems. Thus, the course has attracted much attention and involves participation of students as well as teaching staffs and employees in diverse enterprises. Based on users' experiences, assessment and improvements of existing web-based project management system (PMS), this study aims to establish an online capstone course support system available via wired and wireless Internet connections. To support PDL, a knowledge utilization system (KUS) is developed as an open system utilized by internal students as well as external participants from diverse industries and also as a self-proliferation system enabled collection and accumulation of information from internal and external sources. The established system represents an efficient and effective system that facilitates PDL in capstone course.

Keywords: capstone course; participant-directed learning (PDL); project-based learning (PBL); capstone course support system (CCSS); knowledge utilization system (KUS); industrial engineering (IE)

1. Introduction

Industrial practices usually require that students who in majored engineering disciplines be equipped not only with knowledge of their major but also other competencies such as communication skill, collaborative capability, team skill, systematic thought and leadership, as well as an understanding of business issues associated with legal or environmental concerns [1]. To cultivate students equipped with such a diverse background, engineering colleges typically provide students with capstone courses. Capstone courses are based on participant-directed learning (PDL) by means of open-ended, real-world problems for which teams consisting of students and other participants are usually organized, depending on the type of problem. Project-based learning practices have been adopted by most engineering colleges [2, 3].

Capstone courses are generally taken by senior students as a gate to achieving their academic degree. Typically, in one or two semesters of the course, teams define a problem, plan their approach, propose creative solutions, analyze the proposed solutions, produce or implement the solutions and then communicate them internally and externally. Participation in capstone design provides students with the opportunity to transition from student communities of practice to professional communities of practice; i.e., from the classroom to industry. Working with a client-advisor from the field (industrial engineers, start-up companies, company representatives, teaching staff, laboratories, alumni, etc.) in a type of apprenticeship, students are challenged with real-world needs. While students taking capstone courses are not full members of the professional community, contextualizing the problems, needs, or services within the field's practices provides students with the opportunity for situated learning [4] and affords them the opportunity to apply their skills and knowledge toward the development of a robust understanding of what it means to be an engineer. This facilitates an identity shift from student to professional engineer [5].

However, although capstone courses are essential in engineering school and provide students with real experiences and self-directed learning, the execution of real or quasi-real projects based on team work among students produces many difficulties, including routine documentary work, innovative idea generation, searching information and know-how for problem-solving, managing team work and relationships with other participants such as faculty, client firms, alumni and external persons related to their project. Therefore, capstone courses must provide a systematic tool (such as a project management system) to enable participants to resolve such difficulties. Furthermore, because educators are intended to function as guides or coaches facilitating the process of knowledge acquisition by the students in a PDL environment [6, 7], a system that enables knowledge acquisition and utilization to generate an innovative idea and methods to solve

* Accepted 15 May 2016.

their problem can activate student-centered learning as well as encourage involvement in the course by various participants, especially external firms and alumni.

This study aimed to develop a capstone course support system (CCSS) that provides, firstly, students with a project management system (PMS) to facilitate project execution, secondly, besides students, external participants with a knowledge acquisition and utilization system to generate ideas and develop methods of solving problems; i.e., to encourage PDL and finally, educators with an operating system to manage the capstone course efficiently. The remainder of this paper comprises of four sections. We examine PDL as a theoretical background in Section 2. Section 3 explains the existing PMS and experience of the capstone course of the Department of Industrial & Management Engineering (IME) at Hankuk University of Foreign Studies in Korea. Section 4 addresses the development of the capstone course support system, capstone IME®, which includes a knowledge utilization system (KUS) for all participants in capstone courses, such as students, teaching staff and external agents. Section 5 provides concluding remarks.

2. Participant-directed leaning and project-based learning

Theories of learner—or participant-centered education commonly accommodate the viewpoint of constructivism. The constructivistic learning theory had been employed as a subject of educational innovation and thereby also influenced theories of learning and pedagogy. It appeared in the 1970s and became an alternative to conventional instructor-centered learning theory during the 1980s. Since that time, diverse theories of learning have been introduced and applied to education. According to the learning theory of constructivism, learning is not simply accumulation of additional knowledge provided by teachers or instructors but comprises the symbolization of knowledge of learners and the experiential interpretation of the knowledge to facilitate an understanding directly connected with the actual life experience of learners.

Brooks and Brooks [8] defined constructivism education as follows. "Constructivism contrasts with the traditional learning process in a typical class. Traditionally, learning has been regarded as an activity of imitation and it led students to repeat and imitate new information. On the contrary, the lesson of constructivism enables students to internalize, modify and reconstruct new information." Thus, in constructivist learning, the 'participants' as subjects construct knowledge, the 'instructors' as facilitators assist the construction of knowledge by participants. Moreover, the construction of a 'learning course' for practical and appropriate problems (studies) and the problem-solving and collaborative 'pedagogic environment' are emphasized.

The theory of student-centered learning based on constructivism has been adopted by most universities, including the engineering disciplines. Traditional engineering education comprises an introduction to general principles by instructors, derivations of mathematical models based on illustrated principles and explanations on problems and ways of applying the derived mathematical models. Further, problems requiring students to find ways of applying engineering theories and mathematical models in practice were assigned to students and solutions prepared by students were examined and evaluated in written examinations [9]. However, the traditional way of engineering education did not cultivate the necessary competency in communication or teamwork, understanding of issues outside engineering—such as like social, environmental and economic concerns—and above all, the ability to apply engineering knowledge in industry [10].

Therefore, the traditional paradigm of engineering education based on transfer of basic or applied knowledge to students through discipline-oriented, lecture-centered, or application-oriented manners is shifting to a new multi-disciplinary and student-oriented approach based on an understanding of the complexity of technological knowledge. Moreover, teaching and learning are moving towards accommodating inductive approaches [11]. Consequently, problem-based learning (PmBL), project-based learning (PtBL), inquiry-based learning (IBL), discovery-based learning (DBL), case-based learning (CBL), scenario-based learning (SBL), work-based learning (WBL) and just-in-time teaching (JiTT) were developed by incorporating the inductive approach into participant-centered teaching and learning theories. Table 1 shows a comparison of several participant-centered learning approaches with respect to the participants, objects of learning and associated features. This comparison is subjective; however, the PtBL, PmBL, CBL and SBL approaches seem applicable to engineering education.

Among these approaches, PtBL is similar to current engineering education in that it starts with an assignment requiring students to carry out more than one project task with tangible outcomes (such as products, blueprints, models, or computer programs etc.) [9]. Palmer and Hall [13] based on the results of previous studies defined PtBL as integration of the following components. First, it pursues a solution of target problems or intends accomplishment of tasks by learners through educational

Table 1. Comparison of learner-centered learning theories (revised from [9] and [12])

	P_mBL	P_tBL	IBL	DBL	CBL	SBL	WBL	J_iTT
Problem context for learning	2	2	**1**	2	2	3	4	2
Complex, ill-structured, open-ended real-world problems for learning	**1**	3	4	4	2	3	2	4
Major projects context for learning	4	**1**	4	4	4	2	3	4
Case study for learning	4	4	4	4	**1**	3	3	4
Students discover course contents	2	2	2	**1**	3	2	2	2
Active learning	2	2	2	2	2	2	2	2
Collaborative/cooperative learning	2	2	4	4	4	3	3	4
Sum	**17**	**16**	21	21	**18**	**18**	19	22

*1—by definition; 2—always; 3—usually; and 4—possibly.

activities that induce learning. Second, the learners should function as members of a project team to complete a project assigned thereto. Third, the projects assigned to teams are typically realistic problems requiring multidisciplinary approaches and a considerable amount of time. Fourth, as discussed above, the projects involve development of concrete artificial outcomes (design, product prototype, computer software etc.). Fifth, the completion of each project requires production of report(s) that provide details regarding project completion, followed by an open presentation thereof. Sixth, instructors function as advisors and coordinators other than authoritarians.

According to previous studies, learners attain the following benefits from PtBL. Firstly, learners participating in PtBL develop teamwork skill and experience. Secondly, the learners can cultivate leadership and sense of ownership in the learning through the problem-solving process. Thirdly, the learners can learn self-regulation, persistence and competitiveness. Fourthly, learners can understand the multidisciplinary and systematic aspects of engineering problems empirically. Fifthly, learners can attain experience that will enable them to better cope with actual engineering problems professionally. Sixthly, learners can learn how to review or reflect on the results of projects and develop documentation, presentation and communication skills. Finally, learners can also deal with incomplete or inaccurate information. In contrast, learners frequently encounter difficulties during PtBL in that the skills or problem-solving methods learned during one project cannot be applied to other projects. Instructors should point out clearly the methods learned previously and ways of applying these methods to new problems; and assist the learners in relating the learned methods or skills to the current project. If necessary, they should provide the learners with pertinent information [14]. Thus, the system provides learners with an environment in which they can solve diverse problems through PDL and with the necessary information for engineering disciplines.

3. Capstone course and lessons from a PMS in industrial engineering

3.1 IE capstone course

In general, the capstone courses in colleges of engineering last for one or two semesters in the fourth year. In the case of the Department of Industrial & Management Engineering (IME) at Hankuk University of Foreign Studies in Korea, such a course has been provided for fourth-year students for over 10 years during spring semester and is worth five academic points. The students taking this course select their teams and projects autonomously. Usually, the teams comprise three to five members. Although the projects are based on real problems, they come in diverse types: projects formulated by students themselves from needs of the industrial sector, projects proposed by faculty members from their private or public contract R&D projects, projects proposed by the needs within the engineering school, projects based on subjects of competitive exhibitions held by outside institutions, etc. Among them, projects concerned with actual industrial issues are usually recommended to students. In fact, nearly 80% of capstone design projects are associated with actual industrial issues.

The capstone design course system of the Department of IME at Hankuk University of Foreign Studies is shown in Fig. 1. The capstone design course consists of the following four components: the participant (project team), the project itself, the educational system of the Department of IME that provides necessary knowledge & information and the system supporting the performance of each project. Thus, each project team interacts with the other three components.

The one-semester capstone design course comprises the following three activities: selecting the

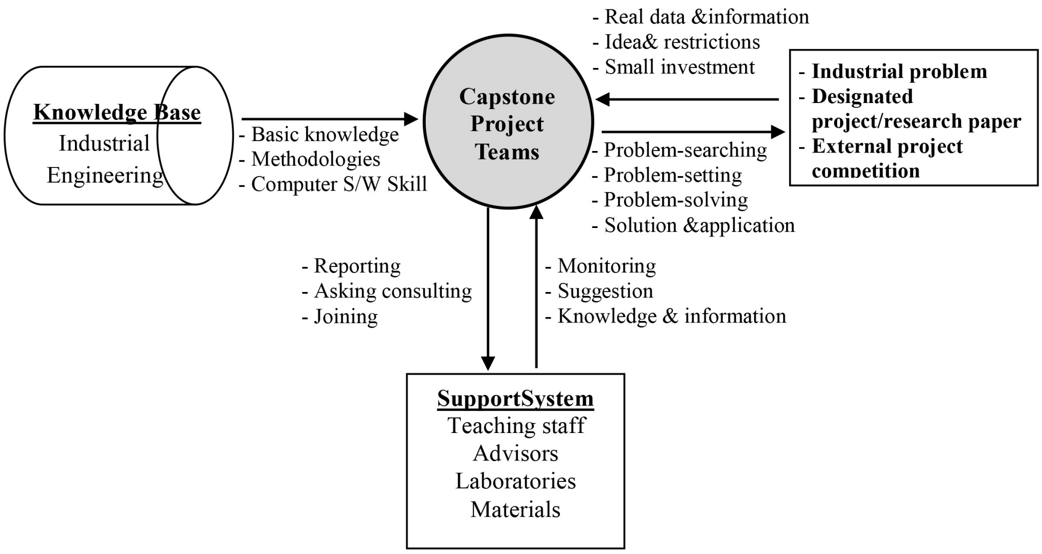

Fig. 1. The framework of the IE capstone course.

project, providing an intermediate presentation and providing a final presentation. However, in practice, the activities of each project can be divided into the following: preliminary activities involving preparation of prerequisites for the project, the actual educational course and the post-semester course in which the project outcomes are exploited. In the preliminary course to be carried out before the semester, the activities such as team organization, the search for a project and the preliminary survey and studies associated with the project are carried out. The educational course is initiated upon appointment of dedicated teaching staff to each project team, together with the determination of the final subject of each project. During the semester, each project team provides a biweekly presentation of their project's progress and the informal project activities are facilitated by meetings with dedicated teaching staff. Through frequent visits to, and meetings with, industries, the project team can learn about real industrial issues and explore methods of coping with such issues. The outcomes of the project team's activities are assessed during the final presentation; all project teams must submit final reports and project outcomes (prototypes, programs, information systems, business models, results of analysis etc.). The academic score of each project team and members thereof (students) is determined by assessing the subject of each project and by the intermediate and final appraisals. A departmental support system should be established for post-semester application or exploitation of the outcomes of each project after completion of the capstone course. Thus exploitation of project outcomes such as subscribing to external competitions, patent applications, contributions to journals, software registration, or industrialization of developed or established technologies will be encouraged by providing pertinent information, expenses and human resources. Teams usually carry out such activities autonomously during the summer vacation after course completion.

Capstone courses based on project-based learning are important as they cultivate diverse skills and capabilities of participants. Indeed, the program requires much time and effort by not only students but also teaching staff. Therefore, a PMS can assist students with scheduling of project progress or preparation of minutes of project meetings; for teaching staff, an automated system that assists with control and monitoring of project progress and outcomes was needed.

3.2 Lessons from the existing web-based IE project management system

A web-based PMS assists with scheduling and management of project progress and outcomes was completed in the autumn of 2014 and introduced to the capstone design course in 2015. In 2015, the capstone design course comprised 51 students in 13 project teams; and 9 professors each advised 1or 2 project teams. Ten projects (77%) were concerned with general industrial issues, two intended to produce an academic paper and one was based on a professor's research project. Most of the teams conducted the project activities autonomously. Projects covered a diversity of subjects including inventory management, development of a new business model, development and application of a simulation model, establishment of an information system, quality certification system, new product development, business support system, or production and distribution management. At the final evaluation of the capstone course, the 11 of the 13 projects passed, for a success rate of 85%, considerably higher than the 60–70% attained in previous years.

Project teams enrolled in the Web-based PMS at the start of the semester and established a schedule to manage project progress and upload outcomes, minutes of meetings etc. using the Web-based PMS. However, several requirements based on the inconvenience of the system were identified from 37 questionnaires regarding satisfaction with the Web-based PMS conducted after completion of the capstone course [15]. The questionnaires evaluated the overall degree of satisfaction, convenience and usefulness of the Web-based PMS on a 5-point scale. The necessity and the overall degree of satisfaction with the PMS scored above average (3 points).

However, a need for a new system to facilitate knowledge acquisition and support PDL by providing project-related information and knowledge, multidisciplinary problem-solving methodology and information of actual project cases etc. was revealed. Moreover, the usefulness and convenience of the existing PMS were requested to be improved. The questionnaire items with the poorest scores for the existing Web-based PMS are shown in Fig. 2. The students stated that they were dissatisfied with allocation of team members, mutual communication and documentation in the Web-based PMS as well as retrieving project-outcome information or problem-solving methods. Therefore, a new PMS was developed. Indeed, the introduction of a new Capstone Course Support System (CCSS) to support the capstone course and PDL rather than modification of the existing system was concluded to be reasonable based on experience with the system and the questionnaires. The development of the new system and its overall configuration and details are described in the next section.

4. Development of a capstone course support system and knowledge utilization system

4.1 The basic development concepts of CCSS

The following three directions for the development of a new Capstone Course Support System (CCSS, namely Capstone IME®, http://capstoneime.hufs.ac.kr) were determined based on the evaluation of the performance of the existing Web-based PMS. Firstly, the structure and functions of a general PMS were used as a reference for development of the new system. Thus the nine knowledge domains in the Project Management Body of Knowledge (PMBOK) of the U.S. Project Management Institute (PMI), which is used as a standard for development of PMS, were employed as a reference model for the development of the new CCSS. Secondly, support for mobile Internet via smart phones or tablet PCs was included. Accordingly, Responsive Web Technology was employed in the design of the new CCSS to support communication and transfer of information among participants. An intuitive user interface and support for mobile computing were taken into account during development. Thirdly, a system enabling the acquisition, sharing and exploitation of knowledge was included in the CCSS. The system functions enabling searching for, sharing, accumulation and exploitation of information required for problem solving were identified as the most desired by students, teaching staff and participants from external enterprises [16]. The system is similar to contemporary knowledge management systems (KMS) employed by enterprises, the only difference being in the information

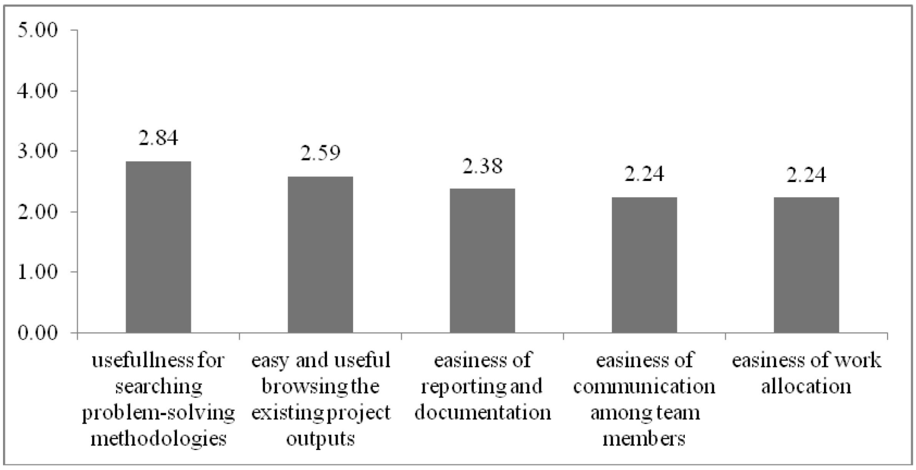

Fig. 2. Web-based PMS items to be improved identified in the survey of participants [15].

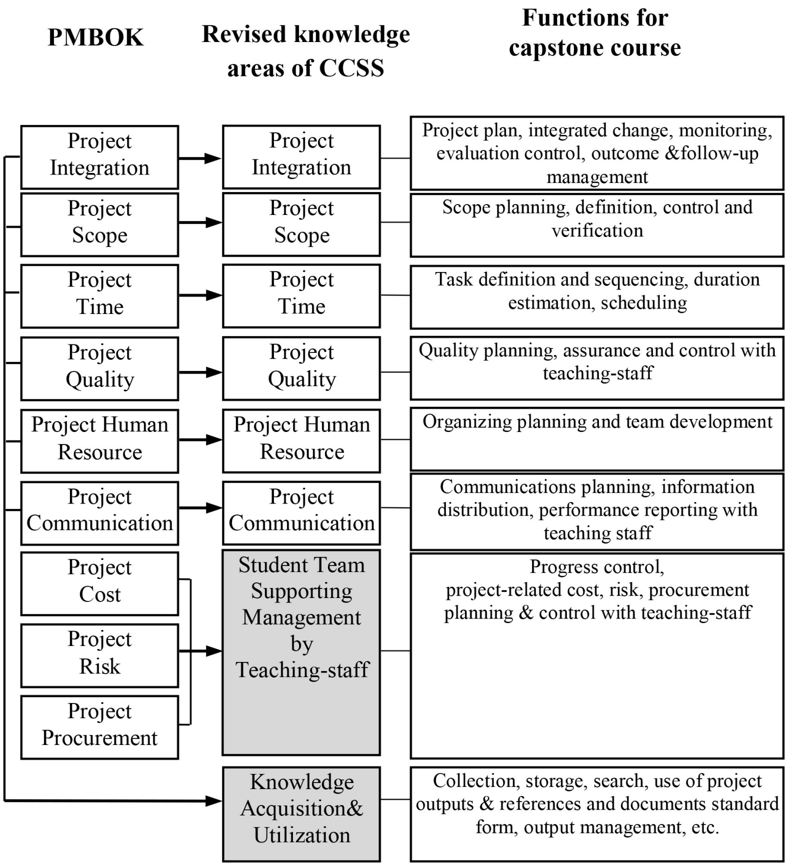

Fig. 3. Knowledge areas and functions for developing the CCSS.

therein, which comprises educational aids such as engineering application methodologies, tools, or information. This system will be developed as the Knowledge Utilization System (KUS) component of the CCSS.

By the basic premise postulating the efficient management of capstone course of the system to be developed, the PMBOK concept, which is essential for the design of effective project management systems, was applied during the design and development of the system. PMBOK is a comprehensive system for the management of new products and services by enterprises. In PMBOK, the basic system elements required for project management are classified into the following nine domains of knowledge: (1) project integration management to ensure that the various elements of the project are properly coordinated; (2) project scope management to ensure that the project includes all work required and only the work required, to complete the project successfully; (3) project time management to ensure timely completion of the project; (4) project cost management to ensure the project is completed within the approved budget; (5) project quality management to ensure the project will satisfy the needs for which it was undertaken; (6) project human resource management to make the most effective use of the people involved in the project; (7) project communications management to ensure timely and appropriate generation, collection, dissemination, storage and ultimate disposition of project information; (8) project risk management to identify, analyze and respond to risks; (9) project procurement management to acquire goods and services from outside the performing organization, in which each domain of knowledge is implemented as an individual functions connected to the others to facilitate project management [17].

Figure 3 shows the knowledge domain of the CCSS of the Department of IME based on the knowledge domain required in the existing Web-based PMS and the nine knowledge domains of PMBOK. The acquisition and exploitation of knowledge domain differs from the existing system in that it was prepared to encourage and support PDL in engineering education. In particular, it resembles the typical KMS employed in contemporary enterprises and will be designed as a subsystem of CCSS with independent functionality. Basically, the CCSS was designed to be a closed system for members of the Department of IME; however, the knowledge acquisition and utilization system will be opened to current students, teaching

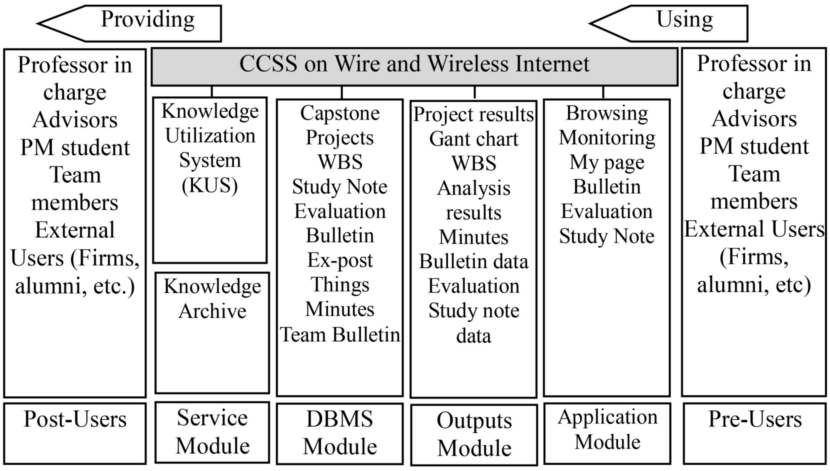

Fig. 4. The architecture of CCSS.

staff, alumni and participants from external enterprises or institutions. The ability of such users to access the system will result in proliferation of knowledge uploaded, classified and retrieved internally and externally by all users. In the PMBOK, the system elements of Project Cost, Project Risk and Project Procurement are independent knowledge domains. However, in an educational institution, these three elements can be regarded as an integrated domain managed by the administrative office of each department; thus the three domains will be integrated into a single knowledge domain and function as a support system to be directed by the teaching staff.

4.2 The architecture and functions of CCSS

The four stages (analysis, design, development and implementation) typically employed in the development of general information systems were also applied to the development of the CCSS. In the analysis stage, the requirements of users of existing Web-based PMS were examined and the basic direction and reference model thus derived is presented in section 4.1.

In the design stage, the overall system configuration; i.e., the system architecture, defined as the relationship between internal components, is derived. Fig. 4 shows the system architecture derived according to the basic concept and development direction of CCSS. In the system architecture, the four types of user—the professor in charge, the advisor-to-team, project teams of students and alumni and external participants from enterprises—are defined. The defined users can access the system via an application module in the CCSS over the Internet and the project outcomes can be uploaded through the output module to be stored by the Data Base Management System (DBMS) module in the CCSS. The DBMS module was designed to preserve and manage the knowledge base of KUS. The service module of CCSS consists of KUS and a Knowledge Archive, which provides students with information related to problem solving methodologies, similar cases, methods of exploring solutions to diverse issues, or entrepreneurial information related to the current project. This module is discussed in the following section.

In the third stage, the system architecture and functions are developed by employing the Windows Server 2012 R2 Standard as a web server and JSP, JAVA, HTML, Java Script, CSS as languages with Apache-tomcat, Eclipse (Eclipse IDE for Java EE Developers) as development tools. Finally Microsoft SQL Standard Edition was used for the DBMS.

At the implementation stage, the integrity, consistency and programmatic errors in the developed system were checked and validated via an operational test prior to the capstone course. The CCSS was available through www.capstoneime.ac.kr over the Internet (Fig. 5) from intra- or extra-mural sites through which various users can download or upload information.

CCSS functions were accessed through six menus (Fig. 6). These six menus were developed based on seven knowledge domains (excepting knowledge of student team supporting management, which is covered by the CCSS support manager) defined previously for capstone project management. The main menu of the system comprises the following: (i) KUS menu, which supports PDL; (ii) the My Page menu for project participants (students, teaching staff and external entrepreneurial participants) to plan and control project scheduling; (iii) the Team menu, which comprises the Team Internal Bulletin function by which team members can communicate, (iv) the Monitoring menu, which is designed to support and evaluate all projects and manage the opening and closing of the capstone

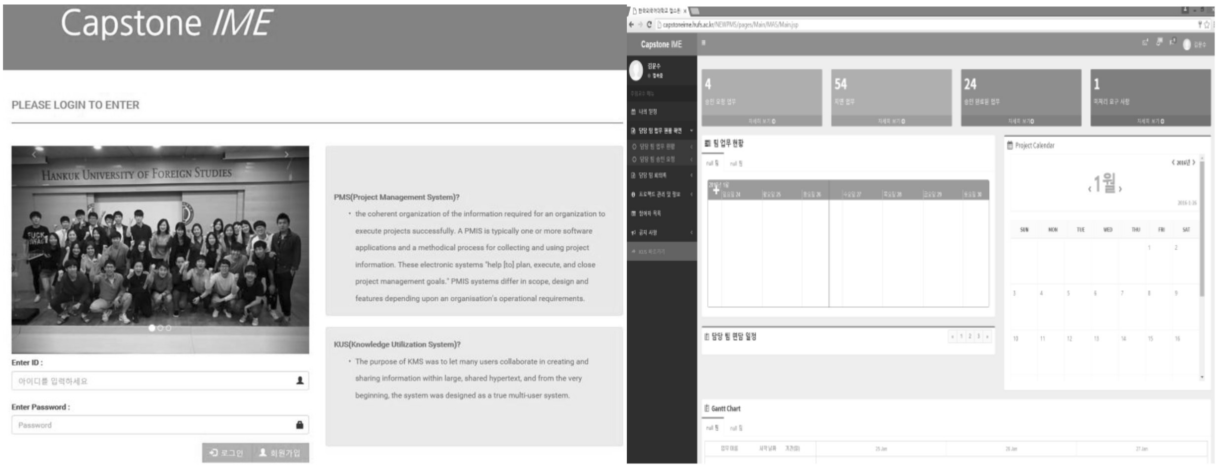

Fig. 5. The initial and main screen of the capstone course support system (www.capstoneime.ac.kr).

course; (v) the Participants Management menu, which is designed to manage and support project participants; and (vi) the Bulletin Board menu, which facilitates communication among the participants in the capstone course.

Figure 7 shows the menu structure of the system manager, which covers knowledge of student team supporting management in Fig. 4. The CCSS support manager enables management of overall system information; participants' information; and facilities' information, including the maintenance, repair and operation of department facilities and hardcopy-typed references, etc. The most important function of the CCSS support manager is not only to support project execution on the CCSS but also to update project-related information, including project history, evaluation, bulletin data, follow-up projects etc.

4.3 Development of a KUS for PDL

The architecture of the KUS was designed to facilitate PDL based on students' assessment of the existing web-based PMS is shown in Fig. 8. The architecture of the KUS was designed based on a general KMS comprising the basic procedures of collection, preservation, sharing and utilization of knowledge. Further, the architecture was also designed to be recursive and self-proliferative through retrieval of problem-solving knowledge stored in the system. In particular, diverse references and data uploaded by external participants can be classified and stored automatically to facilitate search and retrieval of such information, similar to the intramural environment, for students taking part in PDL.

Figure 9 shows the menu structure of the KUS. Through this interface, users can access previous

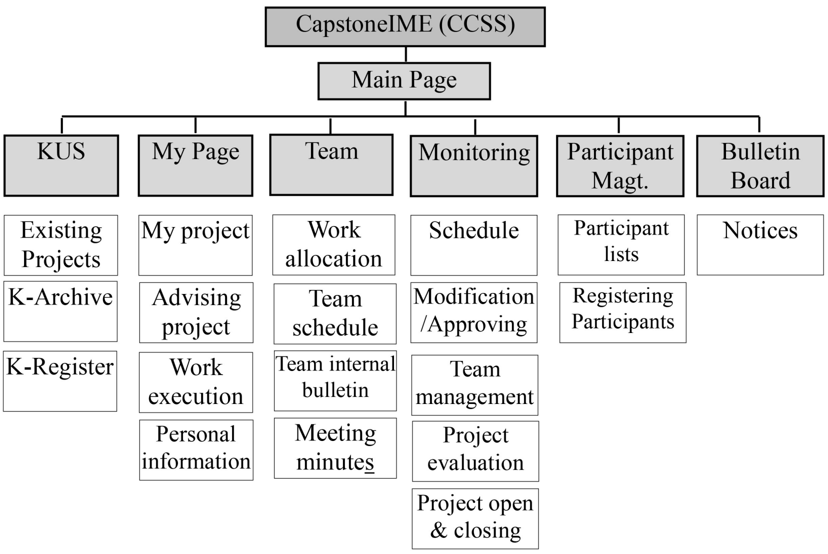

Fig. 6. The main menu structure of the CCSS.

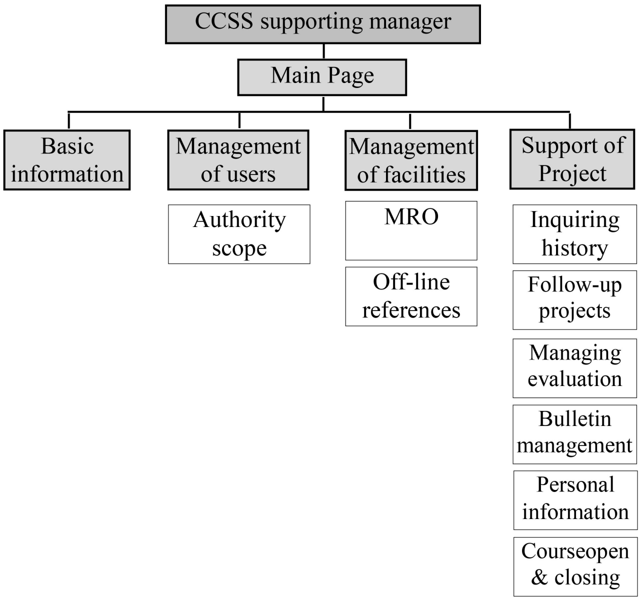

Fig. 7. The menu structure of the system manager for CCSS.

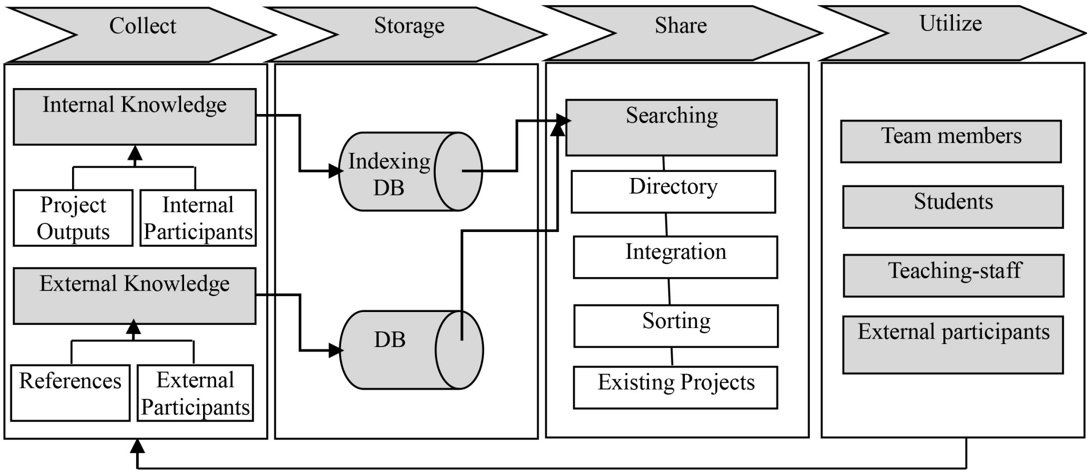

Fig. 8. The architecture of the KUS

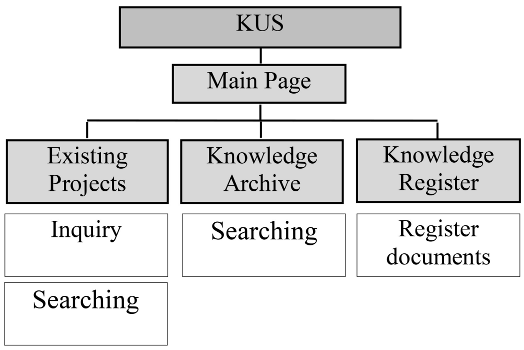

Fig. 9. The menu structure of the KUS.

projects. The information of previous projects comprises the following: basic information of each project, Schedule-Gant chart, project outcomes, minutes of project meetings, of project outcomes etc. Thus participants can easily find benchmarks for their project. The interface also enables users to retrieve information classified according to discipline; this can also be achieved through the Knowledge Archive menu. The Knowledge Archive classifies and stores diverse information uploaded by participants systematically using the Knowledge Register. At this time, the KUS requires improvement to support project problem solving more effectively by reflecting the requirements of participants in PDL.

5. Concluding remarks

The capstone course is a PDL process featuring PBL characteristics and is recognized as an important educational course for students to become professional engineers capable of solving real industrial problems. Therefore, the degree of interest in this program by teaching staff and participants from external enterprises, as well as students, is high. However, intramural students require flexible support to cope with difficult issues encountered in project-based learning. This study aimed to develop an information system to support students participating in project-based learning in the capstone course. Particularly, the users' assessment of the existing web-based PMS was taken into account during development of a capstone course support system, focused particularly on efficient project management.

Comparing to the existing web-based PMS, the KUS was designed to be available to all users, including external participants, to support PDL. The KUS can be exploited through CCSS by participants in project-based learning and was designed to be open to all participants and users not involved in projects (e.g., students in lower classes, alumni, faculty and external enterprises). In particular, the system was designed to be self-proliferating to enable continuous collection of information for future projects. Besides, the system incorporated mobile computing to support students participating in projects. However, the basic principles and requirements for project management were based on the standard PMBOK guidelines, similar to the existing Web-based PMS, to facilitate efficient management of student projects.

Unexpected problems with CCSS and KUS in actual capstone courses are likely to occur, similar to the existing Web-based PMS. Moreover, further improvements desired by students, teaching staff and external participants should be considered and resolved through continuous modification and/or correction. The CCSS and KUS will contribute to the education of engineering students and facilitate PDL by students who hope to become professional engineers capable of solving real industrial issues. Although the developed system is specific to IE, it is likely applicable to capstone courses of other engineering disciplines.

Acknowledgements—This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT and future Planning (NRF-2013R1A2A2A03067925)

References

1. S. Hackman, J. Sokol and C. Zhou, An effective approach to integrated learning in capstone design, *INFORMS Transactions on Education*, **13**(2), 2013, pp. 68–82.
2. S. M. Brown and C. J. Seider (Eds.), *Evaluating corporate training: Models and issues*, Springer, 1997.
3. C. L. Dym, A. M. Agogino, O. Eris, D. D Frey and L. J. Leifer, Engineering design thinking, teaching and learning, *Journal of Engineering Education*, **92**(1), 2005, pp. 7–25.
4. J. Lave and E. ScWenger, *Situated learning: Legitimate peripheral participation,* New York Cambridge University Press, 1991.
5. A. Johri and B. M. Olds, Situated engineering learning: Bridging engineering education research and the learning science, *Journal of Engineering Education*, **100**(1), 2011, pp. 151–185.
6. R. Hadgraft, Problem-based learning: A vital step towards a new work environment, *International Journal of Engineering Education*, **14**(1), 1998, pp. 14–23.
7. E. Montero and M. J. González, Student engagement in a structured problem-based approach to learning: a first-year electronic engineering study module on heat transfer, *IEEE Transactions on Education*, **52**(2), 2009, pp. 214–221.
8. J. G. Brooks and M. G. Brooks, *In search of understanding: The case for constructivist classrooms*, Alexandria, VA: Association of Supervision and Curriculum Development, 1993.
9. M. J. Prince and R. M. Felder, Inductive teaching and learning methods: definitions, comparisons and research bases, *Journal of Engineering Education*, **95**(2), 2006, pp. 123–138.
10. J. E. Mills and D. F. Treagust, Engineering education—is problem based or project-based learning the answer? *Australasian Journal of Engineering Education*, **7**(1), 2003, pp. 2–16.
11. M. Lehmann, P. Christensen, X. Du and M. Thrane, Problem-oriented and project-based learning (POPBL) as an innovative learning strategy for sustainable development in engineering education, *European Journal of Engineering Education*, **33**(3), 2008, pp. 283–295.
12. M-S. Kim, A comparative review on problem-& project-based learning and applied method for engineering education, *Journal of Engineering Education Research*, **18**(2), 2015, pp. 65–76.
13. S. Palmer and W. Hall, An evaluation of a project-based learning initiative in engineering education, *European Journal of Engineering Education*, **36**(4), 2011, pp. 357–365.
14. E. D. Graaff and A. Kolmos, Characteristics of problem-based learning, *International Journal of Engineering Education*, **19**(5), 2003, pp. 657–662.
15. M-S. Kim, Development and assessment of web-based project management system for capstone design course, *Working paper, Hankuk University of Foreign Studies, 2015.*
16. M-S. Kim, A conceptual framework to develop a project management system with multidisciplinary consilience in the capstone design course, *Global Journal of Engineering Education*, **17**(2), 2015, pp. 53–60.
17. Project Management Institute (PMI), *A Guide to the Project Management Body of Knowledge*, 4th ed, Pennsylvania: PMI, 2011.

Moon-Soo Kim is a professor in the Department of Industrial and Management Engineering at Hankuk University of Foreign Studies (HUFS) in Korea. He holds a PhD from Seoul National University in Korea. He gained experience as a project manager at the Electronics and Telecommunications Research Institute (ETRI) in Korea prior to joining the University. His research focuses on technology management and its various application fields, as well as recently, engineering education, especially, student-centered learning theory and practices. Dr. Kim has published papers in several international journals, such as Technology Analysis and Strategic Management, Omega, ETRI J, Tele. Policy, Telemactics and Informatics, Scientometrics and Technological Forecasting and Social Change and others and also in several domestic journals.