Supporting Industrial Engineering Education through DennIE: A Low-cost Knowledge Management System

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Abstract

This paper proposes a knowledge management system that enables supporting and supplementing higher learning education particularly, in the Department of Industrial Engineering and Operations Research. DennIE's goal is to assist the department in enabling in and out of class knowledge be accessible to its community. Knowledge such as technological, procedural, and conceptual can be submitted, reviewed, approved, stored and shared. This helps the whole department in supplementing student education by further enriching and widening educational resources. A group of users were asked to test and use DennIE. A customer satisfaction survey was then administered and yielded promising results in Denny's effectiveness and usefulness.

Keywords
Knowledge Management System, Information System, Knowledgebase, Python

1. Introduction
The University of the Philippines Diliman Department of Industrial Engineering and Operations Research (UPD DIE/OR) is a regional and national leader in providing world-class industrial engineering education, research, and development toward continuous improvement in productivity, quality, and robustness in manufacturing, service industry and information systems. It is one of the eight departments and institutes in the UP Diliman College of Engineering that offer undergraduate and graduate programs recognized by universities around the world.

The department was started in 1965 offering the degree of B.S. Industrial Engineering under the supervision of the Department of Mechanical Engineering. In 1971, the DIE/OR was officially established, becoming the newest department of the College. In line with its goal of maintaining and exceeding expectations as the Center of Excellence in Industrial Engineering education and research in the Philippines, it continues to produce highly qualified global industrial engineering professionals, to conduct continuous and progressive research and development outputs and publications, and to create productive institutional linkages with industry, academe, and the government. Today, the DIE/OR offers three programs namely, the Bachelor of Science (BS) in Industrial Engineering, Master of Science (MS) in Industrial Engineering, and the Master of Engineering (MEngg) in Industrial Engineering.

With a yearly average intake of 110 undergraduate students and 10 graduate students, the DIE/OR is still susceptible to a lower average of BS and MS/MEngg graduates compared to its number of intake. The BS program experiences an average of 91 graduates per year contrary to its intake while the MS/MEngg program suffers an average of 4 students per year. Based on further student interviews (Department of Industrial Engineering and Operations Research 2021), it is revealed that for the graduate students, reasons vary from not being able to complete their thesis and special projects because of insufficient exposure to conducting research.

During the 1st Semester Academic Year (AY) 2022-2023, 32.65% of the BS IE students suffered failing grades for courses which prevented them from taking the next step of their program. It was observed that such a high failing percentage was due to students lacking access to various learning resources, supplemental materials, adjustment to

physical classes and of course, a factor of difficulty of the concerned courses. In addition to the academic knowledge, this research is partly inspired by the recent effects of the pandemic to the IE student experience. It was observed that most undergraduate and graduate students experience lack of specific guidance especially during the pandemic years (2020-2022) in terms of registration/enrollment, student process such as dropping of subjects, and student appeals. In the same term, at least 11.36% of the student population experienced unfinished registration due to lack of knowledge on how to complete their enrollments. While orientations are held for students before the start of registration, students still suffer the knowledge for standard procedures since all the pre-pandemic information dissemination methods were removed. Furthermore, these types of situations placed even greater burden to the administrative offices in terms of electronic inquiries as compared to the pre-pandemic setup where questions are easily answered. Even today, the department is still in the process of providing online and updated procedures and guides for all student processes.

Knowledge can be defined as a familiarity, awareness or understanding of something (e.g., standard operating procedures, facts, skills). Examples of academic knowledge that can be found in the DIE/OR are (1) standard steps in using a software tool (e.g., Minitab) to generate a full factorial model in Design of Experiments, (2) sequential steps in creating a Linear Model in MS Excel, and (3) installation and activation of a virtual environment in Python. Often, there is a lack of available pieces of knowledge that are outside of the usual traditional learning materials like lecture resources, notes, books, or video materials. These pieces of knowledge support the formal learning media and these are not limited to procedures and most certainly not limited to the Industrial Engineering concepts per se. Other examples can include content, media, documents, datasets, research templates and even legal life hacks.

Thus, there is a need for different types of knowledge to be captured, stored, and shared from one DIE/OR member to another so that an effective learning experience can be achieved. Hence, this paper proposes a Knowledge Management System (KMS) that aims to supplement the regular learning process of students as well as the use of Learning Management Systems (LMS). Knowledge Management (KM) is the process of creating, sharing, using, and managing knowledge in an organization (Girard 2020) as opposed to an LMS, which is a system that is used to develop, deliver, and track training or learning content of its students.

1.1 Objectives
The goal of this paper is to present the design framework and implementation of a knowledge management system particularly to the DIE/OR student population. To achieve this, the following are the objectives of this paper:
- Identify system requirements: establish functional and non-functional requirements using use case diagram, 1 diagram, and other requirements modelling techniques;
- Establish a KMS: design, develop, and implement a knowledge management system that is aligned to the DIE/OR's operational strategy and based on design specifications obtained from similar systems;
- To evaluate the effectivity and user satisfaction of the proposed system.

1.2 System Overview
A KMS is an Information Technology (IT) system that captures, stores, retrieves, and manages knowledge to improve understanding, collaboration, and process alignment with its related domain. For companies, this is used as a tool to capture expertise or standards across different areas of the organization and an avenue for these skills to be accessed by other users. These enhance efficiency of employees in performing their daily tasks. The way these systems work is by first acquiring or capturing knowledge from employees that will then be translated into a usable format and inputted into a database system. The database is designed in such a way that necessary information about the entities involved in the knowledge are included (i.e., department, employees, equipment, knowledge, process). After this, the stored data will be organized and presented to an expert for approval. With a well-organized collection of data, user queries and summarized reports can be made to access information and make informed decisions and better actions.

For the DIE/OR, a KMS solution will primarily serve as a readily available information resource system for students, faculty and even alumni members. Given the past and current mode of learning, it has become increasingly challenging for quick exchange of knowledge to occur which is usually done through frequent face to face interactions in the classroom, online classes, or quick consultations. With this, the KMS will be designed to provide its users with the ability to gain knowledge without having to rely and wait on consultation schedules with the teachers, sending e-mail clarifications, hosting conference calls with colleagues, or the like.

2. Literature Review

Knowledge management systems are not new, thus there are currently existing implementations of KMS in the corporate setting. However, only a handful of these KMS solutions are present in educational and academic institutions, especially here in the Philippines. Different KMS solutions and studies were reviewed and considered in the design of KMS for the DIE/OR.

In the Philippines, the Commission on Higher Education (CHED) which is the agency that manages Higher Education Institutions (HEIs) directed that all HEIs produce, create, apply and disseminate different types of knowledge to students and to a wider community. Hence, supporting the production of high-quality research and the advanced of learning and national development **(Commision on Higher Education (CHED) 2009)**.

Currently, course-based learning is not sufficient for higher education anymore. Students must explore additional resources to cope up with course requirements, understand complex lessons and complete project tasks. For a particular course or subject, not all resources are available at any given time for everyone enrolled or any users who just want to access previous resources. In the Tshinghua University, China, a knowledge management system (KMS-THU) was designed and implemented to support its web-based learning system. Its web-based KMS lets users organize and share learning resources and knowledge across its student population. The framework designed involved sharing of knowledge to a group of students before knowledge is made available in the system. The actual system adapted the four-layer structure of the knowledge management theory and was only available in the university's campus network **(**Peng et al. 2013**)**. KMS-THU also implemented an RBAC (Role-based Access Control) which provided different roles to different users. Several teachers and students evaluated the system and found it effective in storing and sharing knowledge.

A study in Laguna, Philippines assessed the practices of KMS in the region of CALABARZON. The aim was to determine the overall awareness and current experience on the availability of KMS **(**Agawin et al. 2019**)**. The study claimed that KMS is beneficial in improving HEIs in their student and administrative services. It was also determined that the use of KMS can have positive effects on the academic achievements of such institutions. The study used a descriptive quantitative research design to evaluate the level of awareness of its respondents (which only included faculty and administrative personnel) on knowledge management practices on a sample of 3 HEIs.

KM in State Universities was also examined in terms of its practice levels. Specifically, Fiscal **(F**iscal 2**019)** aimed to establish the relationship between factors of KM & KM processes as well as Performance Outcomes & KM Processes. The generic framework for knowledge management lists 4 major KM processes namely, knowledge discovery, knowledge capture, knowledge sharing and knowledge application **(**Becerra et al. 2010**)**. The study employed a descriptive correlational design and collected responses from a target sample size composed of faculty members from different State Universities. The research concluded that KM practices are driven by employee motivation and that knowledge application influences the universities' teaching and research performance.

An assessment study of KM concepts of public school administrators on the awareness and perceived benefits of KM in Masbate, Philippines was also conducted. This further explored how public school administrators perceive and know general KM concepts. However, the results suggested that the administrators are only moderately familiar in KM and that the familiarity on KM will serve as initial steps in generating practices and culture in KM (Barredo-Carmen 2018).

Other countries have also implemented and assessed the utilization of KM in academic institutions. A study in Iraq surveyed several Iraqi HEIs and the responses were tested for their correlations between academic performance measures and practice of KM processes **(**Ali Zwain et al. 2012**)**. It also emphasized KM processes such as knowledge acquisition, knowledge storage, knowledge sharing, and knowledge application must be conducted for effective implementation. The study further concluded that the implementation of KM processes is more effective by doing it collectively rather than implementing it separately in the institutional level. A research project was also performed to investigate cultural factors that may affect higher education administration KM in Malaysia **(**Mohamad et al. 2013**)**. This particular research examined if selected factors like knowledge sharing and cooperation factor would have effects on the KM practice in the university administration. However, the study settled that the factors indicated do not have

impact on the use of KM in the administration of universities. Per factor impact, however, it was deemed that other factors may have effects on each other (i.e., leadership vs. available technology).

Another KMS implementation was also accomplished in the National Taiwan University of Science and Technology (NTU-ST) in Taiwan. According to the research, it is difficult to implement an efficient knowledge management in schools due to various reasons ranging from different organizational culture of teachers and the business versions of KMS may not be applicable in the higher learning education setting. Hence, Lee et. al. proposed a processed-based KMS that meet the needs of schools in actual practices **(Lee et al. 2010)**. The proposed KMS featured an APM (i.e., Apache, PHP and MySQL) framework and produced an interface for its users. Satisfaction survey from a case school concluded that the proposed system is effective in providing necessary elements in knowledge management.

Only a limited number of implementations of KMS in schools or in HEIs were found to be existing in the Philippines. This further sets the proposed solution of this research that a KMS for higher education institutions or in a college-level institution must be developed for the learning and educational progress of its constituents.

3. Proposed KMS Framework

Like the conventional KMS, knowledge will be acquired from its users (students, faculty and alumni) which will be translated into a usable format and stored into the database. The database will be designed to house only the most important information about the users, the type of knowledge that will be stored, attributes of the knowledge, and the content involved in executing the knowledge. Before making this knowledge available for consumption, a selected expert volunteer will ensure that the quality of the knowledge is up to standard. The experts, in this case, may consist of members from the faculty or select students which will be determined later as the system is deployed. Once the knowledge is approved, it will be organized in a database system and will be accessed via a user-friendly interface (through a website), making them available for consumption through downloads, viewing, user queries and reports. Figure 1 details the general process flow of the KMS.
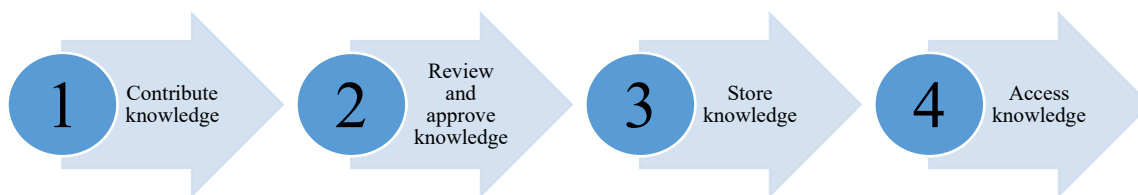

Figure 1. Proposed DIE/OR KMS Process Flow

Based on the four main knowledge management processes, a KMS framework is designed to capture each of these processes. Alternatively, these can be called knowledge acquisition, knowledge storage, knowledge distribution and knowledge use **(Mohamed 2021)**. Figure 2 shows the proposed KMS framework for the DIE/OR based on the KMS theory. The KMS itself will be named DennIE as the researchers agreed upon.

Knowledge acquisition starts when the users, which are made up of students, faculty, and alumni, generate knowledge and submits the knowledge created into the system. The users submit the knowledge and select expert reviewers approve the knowledge so it would appear officially in the KMS. A web-browser based user interface is developed to handle the submission and approval of knowledge created. Then, knowledge is stored in a knowledge database. The database design will take the form of a normalized model (relational design). After the reviewers approve the knowledge, knowledge can then be viewed and downloaded for use through the same user interface. This completes the four main knowledge processes. The proposed KMS framework will be considered in determining the actual user requirements as well as the system design.
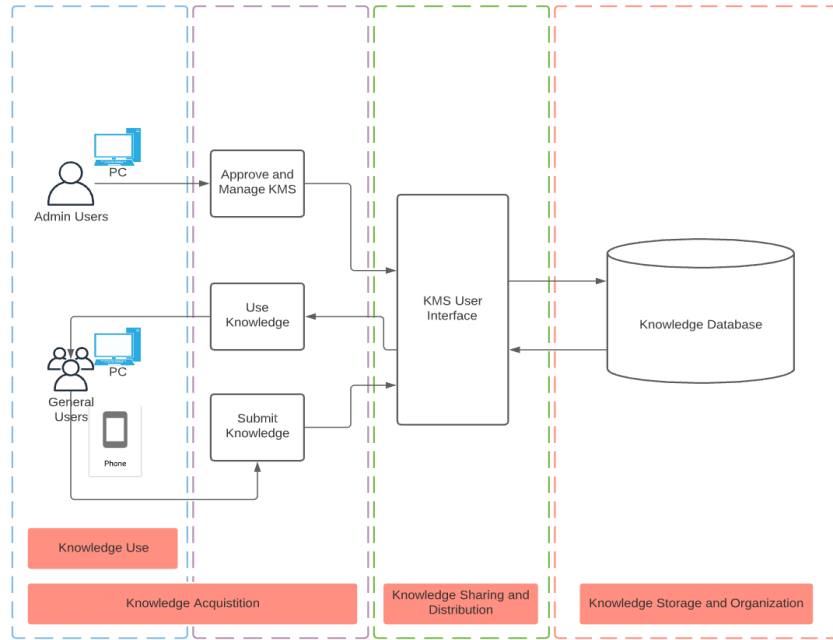
Figure 2. Proposed KMS Framework

4. Data Collection
In order to properly acquire DIE/OR's specific requirements for a KMS, a requirements definition exercise was first conducted through interviews and a survey. A list of functional and non-functional requirements was then determined. Table 1 lists down the complete functional and non-functional requirements determined in the activity.

Table 1. DEnnIE User Requirements

Functional Requirements	Non-functional Requirements
The KMS automatically validates user login requests only grants access to authorized users.	The system must accommodate at least 500 active users (assuming ~110 students per batch across 4 batches + ~20 faculty members) without any signs of performance loss.
The KMS displays a list of the relevant knowledge items that can be selected individually, wherein each knowledge item can be previewed and/or downloaded.	The website must abide by the Web Content Accessibility Guidelines (WCAG) 2.1 set by the World Wide Web Consortium (W3C).
The software allows Administrative Users to grant or revoke access to certain users.	The website must be accessible to users with lesser internet connections by optimizing media files and using style sheets (e.g. minimize inline style to reduce additional data).
The software allows Resource Experts to view and assess pending knowledge uploaded by the users.	The database must remain secure and only be accessible to the Database Administrator.
The Resource Experts can approve or disapprove a pending knowledge.	No sensitive data other than the full name, username, hashed password and student number will be stored in the system.
The KMS contains the following modules: • Browse module wherein users can browse through the existing knowledge. The knowledge will be sorted into categories which can be filtered through by the users. • Upload module wherein users can upload knowledge to the system. • Support module wherein users can choose to contact the IS Operators for help or leave	Users must be given the ability to modify their passwords upon first successful log-in.

comments and suggestions regarding the system.	
The KMS contains the following views: log-in page, home page with query field, browse module, upload module, and support module.	

In addition to the functional and non-functional requirements list, user stories, and a use case diagram was generated. Different roles particular to users namely, the General User, Resource Expert, Administrative User and Database Administrator were also identified. The following user stories were then summarized from the results taken from the interviews and survey conducted:

- As a General User, I can input user queries to obtain stored knowledge
- As a General User, I can browse through the existing knowledge database and filter them accordingly
- As a General User, I can upload and download necessary files to and from the knowledge database
- As a Resource Expert, I can review, approve and disapprove pending knowledge submitted
- As a Database Administrator, I can update the knowledge database, manage user access to the database and make modifications to the database when deemed necessary
- As an Administrative User, I can grant and revoke access to certain users of the KMS

Figure 3 displays the use case diagram based on the user stories. The user stories were also transformed into use cases. The use case diagram features different actors but can then be categorized as roles.
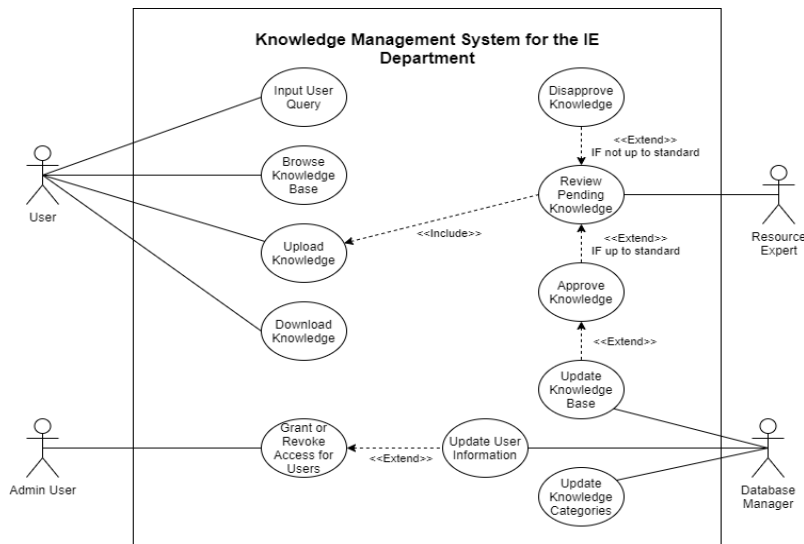

Figure 3. DIE/OR KMS Use Case Diagram

Based on the requirements definition and process diagrams, an entity-relationship diagram (ERD) was then generated. Figure 4 displays the ERD for DennIE. The ERD is composed of 4 major entities namely, Users, Knowledge, Tags, and Categories. The addition of tags and categories were determined after considerable discussion among the researchers. The Users, however, can be further categorized to specific roles such as administrative, general user, database administrator and the resource experts.

To elaborate, each user may upload several pieces of knowledge. There is virtually no limit to the amount of knowledge and queries that the user may input into and from the system. Additionally, users are not required to input user queries nor are they required to upload knowledge; they can just generally view knowledge in the KMS. Lastly, each instance of knowledge contains tags and categories to be used for filtering knowledge later.
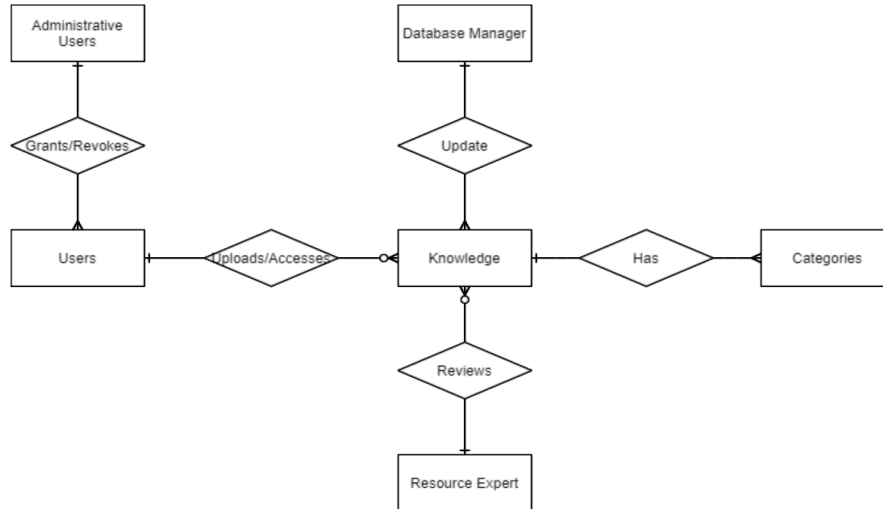
Figure 4. DIE/OR KMS Entity-Relationship Diagram

The ERD was then transformed into a normalized model. The normalized model is the basis database design for the KMS. This type of database design minimizes redundancy in data elements as well as maintain a stable structure. Figure 5 shows the normalized model of the KMS.
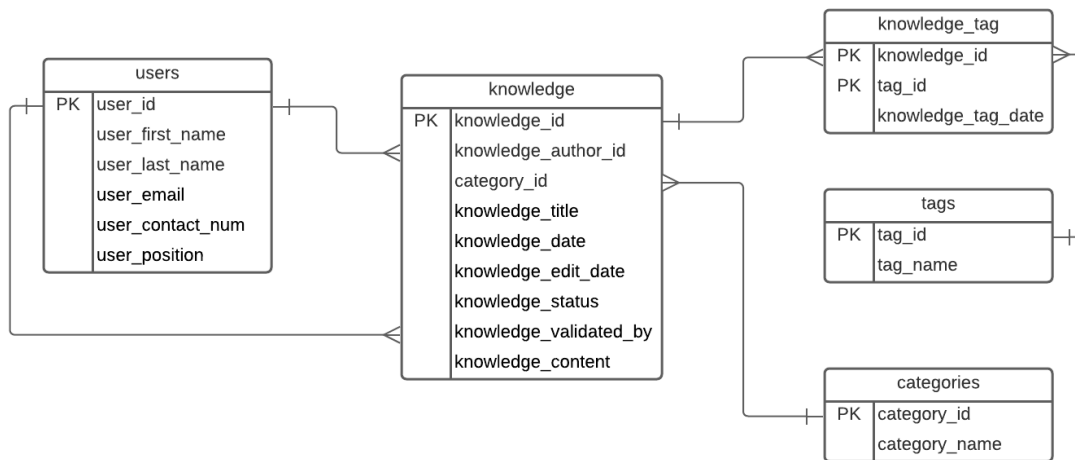

Figure 5. DIE/OR KMS Normalized Database Design

The functionality of the KMS will then include creation of three main entities: Users, Categories, and Knowledge. The "Knowledge" to be included in the system would consist of usable tools, procedures and learnable skills that can be found both within and outside of what is currently taught in the undergraduate and graduate programs. To differentiate, knowledge does not include the Lecture materials, videos, and books. Examples of outside knowledge may include "life hacks", relevant school procedures (e.g., enrollment, dropping, etc.), technical and technology-based knowledge (e.g., installation of PostgreSQL in Windows), document templates (e.g., building a resume), as well as other useful information (e.g., applying for internship, etc.). This study is concerned with processes leading up to the analysis, design, application development and deployment of the KMS.

5. Results and Discussion

5.1 Implementation of the Knowledge Management System

DennIE is built as a web-based system with a database able to store knowledge. The backend component of DennIE was developed using an open-source database management system, the PostgreSQL. On the other hand, the user interface was developed using Python Flask web programming framework. As basis for the database design, a physical database design was also generated from the normalized database design (Figure 5).

When accessing the KMS through the user interface, Users are required to enter login credentials using the User ID and Password. Upon system validation, the User proeeds to use the KMS, whereas an invalid entry will prompt re-entry. If the User has administrative privileges, they have the right to grant or revoke User access. Otherwise, the User proceeds with the general functions and available modules inside DennIE.

The User has two main options, one is to access/download knowledge from the knowledge base, or to upload new knowledge. When accessing the knowledge database, the user may choose to input a search item, or to browse through the knowledge database by using tags and categories. After which, the user may download the knowledge material, or continue browsing, or logout. When uploading new knowledge, it goes into pending approval from a Resource Expert. The Expert may then approve it and update the database, otherwise, it is scrapped.

DennIE is currently deployed in Heroku which is a cloud platform as a service (PaaS) that supports Python programming language. Heroku provides different types of packages offering a free version where one can deploy a website for personal use. In addition, a free version of PostgreSQL database supported by Heroku is added as an add-on to the platform. However, since DennIE supports file uploads, a separate file storage system is needed. With that, DennIE utilizes the free-tier provided by Amazon Web Services (AWS) Simple Storage Service (S3) to store uploaded files. In the future, this may need to be upgraded once knowledge has exceeded the allowable maximum storage for the free-tier. DennIE uses the cheapest package in Heroku for its initial deployment. DennIE can be accessed here: https://dennie-kms.herokuapp.com/. The following figures contain snapshots of DennIE.
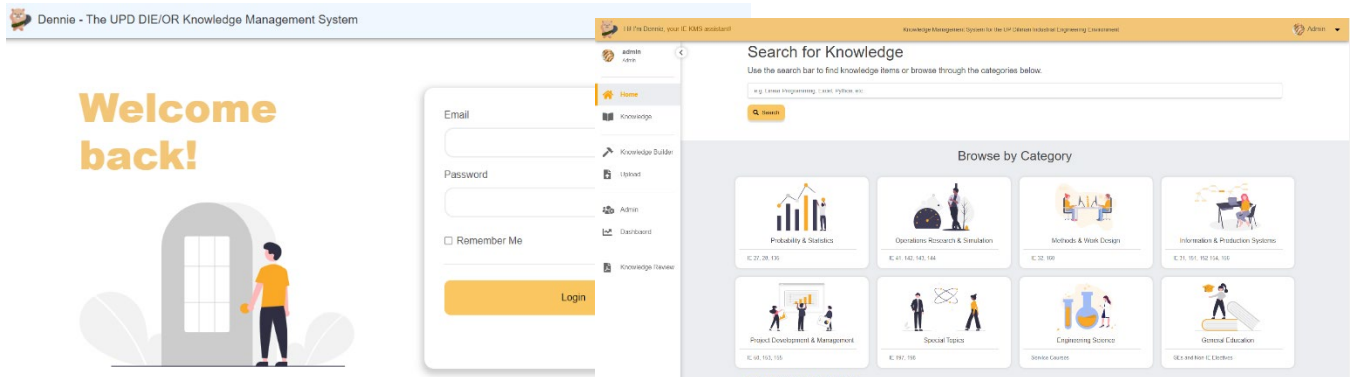

Figure 6. DennIE Home Page and Search Knowledge Page

5.2 Validation

DennIE was initially deployed in July 2021 with initially uploaded knowledge and was only announced to a small number of users. A period of 1 month was considered as the testing and maintenance phase. The proponents were able to gather different views from these users and provided enhancements as deemed fit. To test its effectiveness & user satisfaction, functionality, and content information, a customer satisfaction survey using a 5-point Likert Scale was conducted. A total of 40 respondents used and tested DennIE. The respondents are composed of the following:

Table 2. Respondent Composition

Respondent Type	Count
Undergraduate Student	16
Faculty Member	9
Alumni	9
Graduate Student	4
IT Consultant	2

All respondents were asked to first apply for user account and then test once their accounts are active. They were given an online survey to answer. The questions are categorized into Functionality, Information Content, and Effectiveness. The respondents were then asked to select the level of agreement and the five points of the Likert scale

are described as (1) Strongly Disagree, (2) Disagree, (3) Neither Agree nor Disagree, (4) Agree, and (5) Strongly Agree.

The questions under each category are listed below. Questions on System Effectiveness and User Satisfaction generally asked how the respondent perceives his/her satisfaction of using DennIE as well as provide agreements/disagreements on how effective DennIE is.

A. System Effectiveness and User Satisfaction

    a.   I am satisfied with the overall system quality of DennIE
    b.   I am satisfied with the overall information quality of DennIE
    c.   DennIE can indeed supplement my industrial engineering education
    d.   I am satisfied with DennIE overall
    e.   Overall, I think DennIE is an effective system that caters the needs of the intended users

Figure 9 displays the distribution of responses under System Effectiveness and User Satisfaction. Results show that more than 50% of responses per question strongly agree with the corresponding statement (see percentages in gray). There are other notable observations are observed.

- First, 80% of the respondents strongly agree that they are satisfied with the information quality that DennIE provides.
- Next, 85% of the respondents either agree or strongly agree that DennIE can supplement IE education. However, it is noted that the 12.50% of the respondents are neither agreeing or disagreeing to this statement and 2.50% disagrees. The researchers further asked the reasons why and a number of respondents said that there is a need to increase the number of knowledges uploaded inside DennIE since it is still in the testing phase.
- Third, even if there were some neutral answers, it is observed that 94.87% say they at least agree that they are satisfied with DennIE overall.
- Finally, the respondents seem to agree that DennIE is an effective system that would cater to its intended purpose as out of the 40 respondents answered either Agree or Strongly Agree to the last question. This leads us to say that DennIE is indeed a useful and effective system.
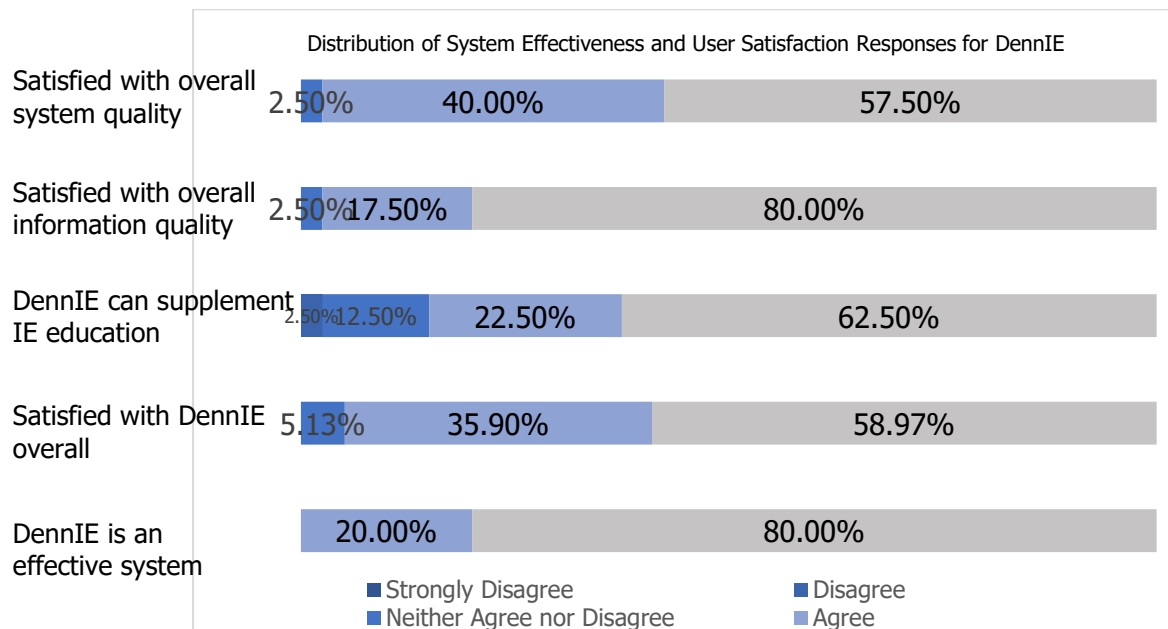

Figure 7. DennIE System Effectiveness and User Satisfaction Responses

The questions on Functionality mostly asked about the features and components of the actual system. It also asked how the respondent feels about navigation and the overall look and feel of the system. Furthermore, it also confirmed if the knowledge can be accessed, uploaded, and downloaded.

B. Functionality

   a. DennIE is easy to use
   b. I am satisfied with overall speed of DennIE
   c. In general, the DennIE functionalities are working as expected
   d. The overall layout of DennIE is easy to navigate and is ergonomic
   e. I am able to successfully upload knowledge
   f. I am able to successfully download knowledge

The next figure shows the distribution of responses according to a type of functionality. Points of observations follow.

- At least 65% of the 40 respondents Strongly Agree on the corresponding statement. This tells us that the features and components of DennIE are working up to standard and as expected.
- There are varied responses on the overall speed as some answered Strongly Disagree and Neither Agree nor Disagree on this question. This suggests that there maybe needed improvements on the loading of pages within DennIE.
- The most critical functions of DennIE are Upload and Download of knowledge. Most of the responses for both functions tell us that these two are currently working as expected, however, 2.50% and 7.50% answered Neither Agree nor Disagree. The researchers probed on the answers and the respondents said that they did not try these two features due to some reasons during testing.
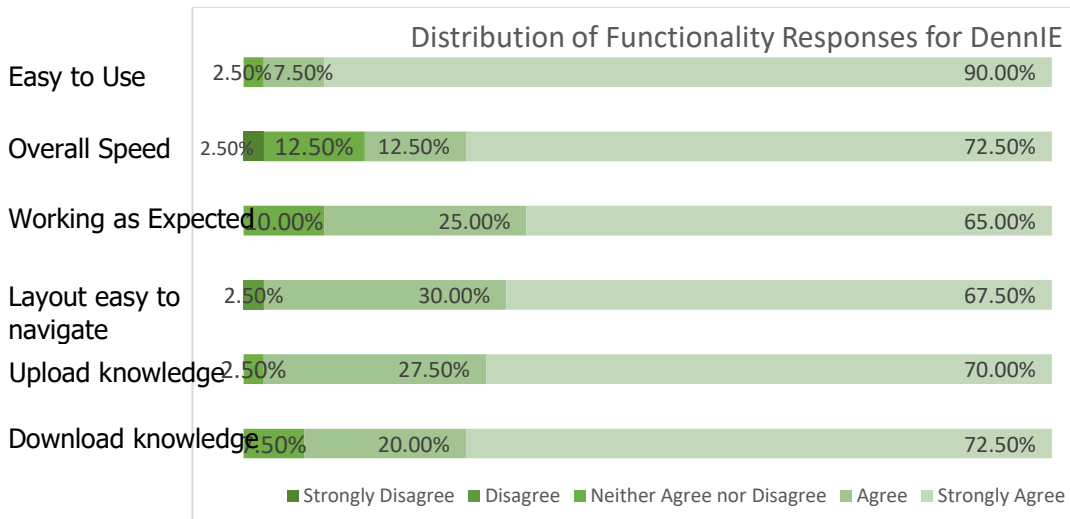

Figure 8. DennIE Functionality Responses

Information content questions generally ask questions on the actual knowledge content and how the sets of knowledge can be useful and relevant in pursuing college and graduate studies.

C. Information Content

   a. Information content in DennIE are always current and timely (timeliness)
   b. Information content in DennIE is accurate (accuracy)
   c. Information content in DennIE is relevant (relevance)
   d. Information content in DennIE is useful (usefulness)
   e. Information content in DennIE can potentially help me in my studies (potential)
   f. Information content in DennIE can indeed supplement what is being taught in classes

The responses are described by Figure 9. Overall, respondents say that knowledge contents of DennIE are indeed useful, has potential in helping in studies and can be supplementary to the current learning system (at least 80% of respondents). Other observations are as follows:

- 90% of the respondents say that they at least agree that the information content of DennIE are indeed relevant to what they do in their current studies.
- However, it is important to know that a significant 7.50% and 27.50% at least disagree and neither Agree nor Disagree that the information content are timely. This may indicate that the information content may not be needed at the current time and that the initial knowledge uploaded are not current or new knowledge. The researchers agree that time and user contribution is need for DennIE to have more knowledge.
- Lastly, 15% say they at least disagree that information content is currently accurate. When asked, the corresponding respondents stipulated that system should have reviewers on the knowledge to be uploaded. It was furthered suggested that these reviewers are credible and preferred to be faculty members. The researchers, at the time of testing, included a faculty member who reviews and approves the knowledge uploaded. This may have to be further enhanced and include more credible and expert reviewers.
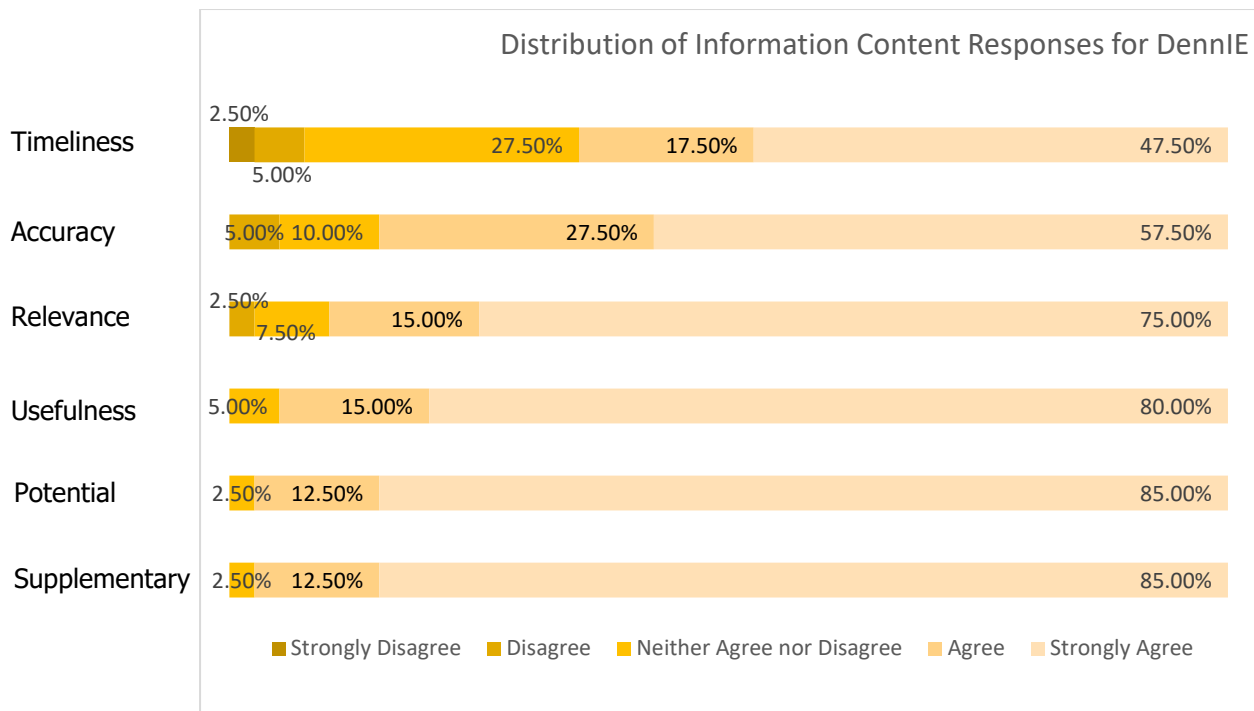

Figure 9. DennIE Information Content Responses

6. Conclusion

This paper proposed a low-cost knowledge management system (DennIE) that enables supporting and supplementing higher learning education particularly, in the Department of Industrial Engineering and Operations Research. DennIE's goal is to assist the department in enabling in and out of class knowledge be accessible to the IE community. Knowledge such as technological, procedural, and conceptual can be submitted, approved, stored, and shared. This helps in supplementing student education by further enriching and widening educational resources. DennIE was designed and built using a relational database management system and Python programming language for its user-interface. DennIE was deployed in Heroku which proved to very cost-effective by taking advantage of the free-tier packages.

A group of users were asked to test and use DennIE for a period of 1 month. A customer satisfaction and effectiveness survey were conducted and generated promising results in DennIE's functionality, information

content, effectiveness and user satisfaction components. The survey respondents also emphasized that DennIE needs to have a lot of active users to increase the number of knowledges uploaded. This recommendation is expected to foster the sharing of knowledge to its intended audience. Future improvements based on the feedback are planned and will be implemented by the proponents.

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Biography

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