Variability Management in Software Product Lines Online Learning Applications

Suhaina Mohamed Zaki, Radziah Mohamad, Shahliza Abd Halim and Nor Bahiah Ahmad
Faculty of Computing, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor, Malaysia.
aina9880.kkpg@gmail.com

***Abstract*—The process of learning and teaching online learning has undergone many changes in line with technological developments. Education institutions have begun introducing new methods of learning this. However, it needs a huge amount of labor intensive to produce and maintain educational technologies due to its huge size (literacy, vocational education, school education, engineering and medical education) and huge variants (language, dialect). With the growing demand and at the same time would like to reduce the factor of cost, time and effort is long, then the need for an effective solution allowing rapid system development. A Software Product Line (SPL) approach is one of the best methods that can be used to develop an educational software family. This research focuses on core asset by recognizing and representing variability in variability management. The study employed two phases of activities in data gathering, there are filtering out data from secondary sources which detail out the features of e-learning and constructivist learning environment of each Virtual Learning Environment (VLE). Second phase involved the use of expert interviews to determine the features of each higher institution e-learning and identify Primitive Requirement of Malaysian Higher Education online learning. Commonality and Variability Analysis (CV Analysis) method has been used as identification of commonality and variability. This analysis is to develop a feature model which further helps in visual representation variants requirements and enhance reusability in the context of product line approaches. As a result, there are 20 Primitive Requirements (PR) has been identified and clearly divided into two categories, common and optional. The frequency in each application of online learning is used to determine whether the PR is reusable. The identification and representation will increase the potential for reuse and help in publishing the specific requirements of the application in the development of the product line.**

***Index Terms*—Domain Analysis; Online Learning; Software Product Lines; Variability Management.**

I. INTRODUCTION

The internet has undoubtedly changed the way people perceive education, and undoubtedly, there is a growing interest in new approaches and innovations particularly for web-based learning. Learners nowadays are knowledgeable in the utilization of smartphones, text messaging and web browsing, thus it is fairly easy to encourage them to take part in online courses. The Internet has really eased the process of content delivery and empowers new learning methods, resulting in the widespread utilization of online learning.

Hence, online learning is rapidly changing as the Internet is making everything to be open and readily accessible to everybody. Because the technologies used to produce interesting courses is rapidly changing, thus to remain relevant, course contents should, one way or another, cope with these changes. Course contents need and ought to be revised periodically to present students with the most recent data.

Online learning has many aliases, among them: virtual education, Internet-based education, web-based education, and education via computer-mediated communication. The Web-Edu project defined online learning based on Desmond Keegan's (1988) characterization of distance education [1]. They described online learning as:

i. the utilization of Internet to offer or disseminate educational matters
ii. the use of two-way correspondence using the Internet so that students may benefit from the arrangement among themselves, as well as educators, and support staff.
iii. the partition of instructors and learners which differentiate it from personal education
iv. the pressure of an educational association which differentiate it from self-study and private coaching
v. the arrangement of two-way correspondence by means of a PC organize so understudies may profit by correspondence with each other, educators, and staff.

Technologies employed in online-based learning ought to be tailor-made to ensure that they suit their target audience. It is important that these applications can be used in many scenarios to cater [2]:

i. different e-learning platforms;
ii. different learning strategies, subjects
iii. organization of courses;
iv. different environments.

II. WHY IT IS HARD TO PRODUCE ONLINE LEARNING?

Educational technologies can be utilized in different situations and settings. There are powerful tools that are able to assist teaching/learning activities. However, it needs a huge amount of labor intensive to produce and maintain educational technologies due to its huge size (literacy, vocational education, school education, engineering and medical education) and huge variants (language, dialect). Although several methods exist to tackle this (for example IMS Learning Design, E2ML, PALO, coUML and standards like SCORM, IMS Global Learning Consortium, and AICC), yet, in terms of technology, the effort made is not worth it from an instructor's viewpoint. Unfortunately, the strive in producing and retaining huge scale and different types of educational technologies is commonly perceived as a type of content development and infrastructure management, often overlooking the software engineering aspects of this issue [3].

It is not easy to produce high-quality educational software. It requires a huge amount of capital, time-consuming, and is

usually performed in special cases, for example as students' research projects in universities. Studies found that, in extreme cases of highly computer-managed learning, at least 100 hours of programming is needed for one hour of instruction [4]. The process of creating a new interactive system needed by instructors and lecturers is not cheap. This is because there will be extra cost related to specifying, developing and testing the system with the final users which are teachers and students [4].

Developers use different approaches in the process of developing an educational system. Specific approaches are used in specific situations. In the development of systems which offer extreme interactivity tasks, problems during their development include the difficulties to handle component repositories and the absence of a systematic process that is able to support code reuse.

Despite the fact that the project development team may produce a versatile that is adaptable and able to accommodate e-learning application and handle the variations stated before, yet these adjustments need to be manually performed, making it be a troublesome, expensive, tedious and error-prone task.

From the viewpoint of software engineering, endeavors for development and maintaining of such systems is a bit high, including several challenges as stated below [5]:

i. Insufficient of a uniform product organization and software production process in every e-learning systems.
ii. Insufficient of accessible common items for production and customization in every e-learning systems
iii. Difficult to share and transfer knowledge and ideas between different fractions of e-learning systems.
iv. No single universally accepted domain understanding and development of the e-learning systems

III. IMPORTANCE OF SOFTWARE PRODUCT LINES (SPL) IN ONLINE LEARNING APPLICATIONS

One of the most important aspects of online learning applications is on the development and improvement of different software and digital content. The complexity and effort needed to produce and preserve learning technologies can be minimized with Software product lines (SPL) approach. SPL is a paradigm used to enhance the efficiency of a family of systems as highlighted in Figure 1 below. Its goal is to demonstrate a normal situation in software product line. This figure portrays how the aggregated production cost of a set of similar but quite different software products mature with the quantity of software released. In the figure, two plots are given for software product line engineering and single-system engineering approaches [2].

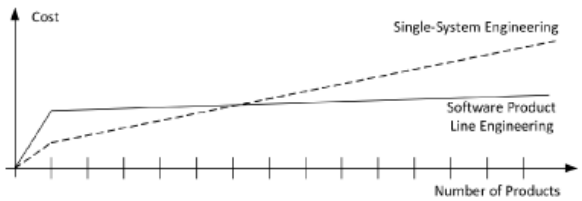

Figure 1: Cost-effectiveness plots for Software Product Lines

A Software Product Line (SPL) approach is one of the best methods that can be used to develop an educational software family. The importance of SPL in online learning applications are:

i. less expensive and is able to enhance maintainability during software development code reuse process [4].
ii. to overcome the limitations of Learning Management System (LMS), and on the other side, to provide institutions with e- Learning applications that fit their own requirements and at the same time share the development work of a set of product using common means of production, in order to reduce the costs and effort of development, maintenance and test, decrease time to market and improve quality. [6].
iii. SPL can help to the development of software auxiliary applications for e-learning platforms where it carried out practically with no cost in order to fit it with the requirements of a specific customer, since this process is performed automatically. The process is executed by a computer can avoid human mistakes, assuring product quality and reducing cost associated to fixing human mistake. [7].
iv. the effective utilization of software assets in e-learning, thus reducing considerably the development time and cost of software products. [8].
v. there is a challenge to produce and maintain online learning systems to be used by large scale and different types of systems with a lot of constraints. Many proofs are available on the use of SPL to improve the efficiency of various domains [5].

IV. VARIABILITY MANAGEMENT

Variability analysis is most important in the development of core assets [9]. It captures what is common across the entire systems domain. Variability itself own is a key concept in SPL. Therefore, it is important for variability to be identified and represented early in the requirements phase [10]. In the development of a product family, variability is the perception of how the members of a family may be different from each other [9].

Variability management is the main activity that affects SPL success. Variability refers to the ability of artifacts to be configured, adapted, extended, or modified for use in a particular context [11]. Commonalities and variability are modeled from the perspective of product features, stakeholder visible characteristics of products in a product line that are of stakeholders' concern [12].

The study employed the following phases of activities in data gathering:

First phase involved, filtering out data from secondary sources such as journal papers and proceeding papers, which detail out the features of e-learning and constructivist learning environment of each Virtual Learning Environment (VLE). A result from this phase has been tabulated in Table 1.

Second phase involved the use of expert interviews to determine the features of each higher institution e-learning. The main objective behind this procedure was to identify Primitive Requirement of Malaysian Higher Education online learning. Three higher education has been identified, there are University of Technology Malaysia (UTM), Open University Malaysia (OUM) and Pasir Gudang Community College (KKPG). The experts involved lecturers from UTM and KKPG whereas from OUM is a tutor. These experts are either administrator of e-learning or e-learning user.

Before proceeding with the expert interviews, a request was

sent via e-mail and followed by fixing of appointments and subsequent conduction of the interview. During the interviews, the experts fill up the table that indicates the features for each institution. Afterwards they were transcribed for further analysis.

We have used Commonality and Variability Analysis (CV Analysis) to extract the common and variable features of our product line [9]. CV Analysis promises an objective decision in requirements identification [10]. This method begins by identifying primitive requirements (PR) or transactions that affect the external actors. One PR may consist of a number of use cases or several PRs may consist of a single use case. Hence, in this method, PR has its own specification which contains behavioral and statistic elements. In the analysis, the frequency ratio will determine whether the PR is usually or optionally used in the domain. Thus, in the CV Analysis method, PR is an important element and used as building blocks to develop use cases.

V. Features and Capabilities of Virtual Learning Environment (VLE)

A virtual learning environment (VLE) is a collection of education tools created to improve students' learning experience by the use of computers and the Internet. The goal of VLE is to enhance students' experience and encourage flexible and exciting education [13].

Table 1 shows the comparison on online learning platform based on constructivist learning environment. The purpose of this comparison is to analyze the commonalities and variability between VLE products and the result will be used in identifying primitive requirements (PR).

Table 1
Comparison on Virtual Learning Environment (VLE)

No	Learning environment	Tools	LON-COPA	Desire2 Learn 8.1	ANGEL Learning Management Suite	TeleTOP VLE	The Blackboard Learning System	Sakai 2.3	dotLRN/OpenACS	Scholar 360	Atutor 1.5.4	Moodle 1.8
1	Instructive	Course Management	√	√	√	√	√	√	√	√	√	√
2	Situating	Authentic activities	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3	Constructive	Discussion Forums	√	√	√	√	√	√	√	√	√	√
4	Supportive	Student Community Building	X	√	√	√	√	√	√	√	√	√
5	Communicative	E-Mail	√	√	√	√	√	√	√	√	√	√
6	Collaborative	Groupwork	√	√	√	√	√	√	√	X	√	√
7	Evaluative	Online Grading Tools	√	√	√	√	√	√	√	√	√	√

From the comparative studies by [14], 10 VLE products has been selected, including LON-COPA, Desire2Learn 8.1, ANGEL Learning Management Suite, TeleTOP VLE, The Blackboard Learning System, Sakai 2.3, dotLRN/OpenACS, Scholar360, Atutor 1.5.4 and Moodle 1.8 and the first comparison is based on the features and capabilities of VLE tools. The comparison has two answers, Y or N. Y means the product has the feature and N means the product does not has the feature.

For Instructive learning environment, all platforms have Course Management tools. Tools can include courseware catalog, course documents as instructional strategies, while MOOC uses Educational Video, Audio files, Documents, Presentation files, hypertexts, Projects and m-learning uses Audio and video-conferencing.

Situating learning environment indicates learning using Situational problems with interesting solutions as authentic activities, problems, or scenario for students. Such programs include field trips, cooperative education, music, sports, and learning laboratories session. However, no pedagogical approach is defined.

Constructive learning environment requires contribution to discussion forums, thus, all platforms need to use the Discussion Forums. Aside from this tool, Synchronous and Virtual classroom tools can also be used in this environment.

Next, for Supportive learning environment, only LON_COPA platform that does not use Student Community Building tool. Other tools used include Resource center to help in making decision, E-mail to experts, FAQs, Tips, Threaded Discussion, Access to e-Tutor / Coach, E-classmates, Peer support and Classroom support.

Communicative learning environment is for students to participate in conversations, and E-Mail tool is used by all platforms in this environment. Discussion board, Announcement board, Synchronous and Announcement are other tools that can be used in this environment.

For Collaborative learning environment, only Scholar360 does not use Groupwork tool. This learning environment also uses E-Mail, Discussion board, and Announcement board tools.

Online Grading is the tool used by all platforms for Evaluative learning environment. Other tools used include learner progress Tracking Assessment, Course Instructor's evaluation, Quiz Peer assessment and Performance & Improvement-based grading.

From this comparison, showing almost all the VLE has features and capabilities based on constructivist learning environment. The results of this analysis will be used as a reference to the CV analysis of online learning in Malaysian higher education. Hence, these features are valid to be used as primitive requirements (PR).

VI. Case Study of Malaysian Higher Education Online Learning

The case study has been done in Malaysian higher education online learning from three different higher education but using similar types of online learning; Universiti Teknologi Malaysia e-learning (UTM), Open

University Malaysia VLE (OUM) and Pasir Gudang Community College e-learning (KKPG). Figure 2 shows the phases in analyzing the case study.

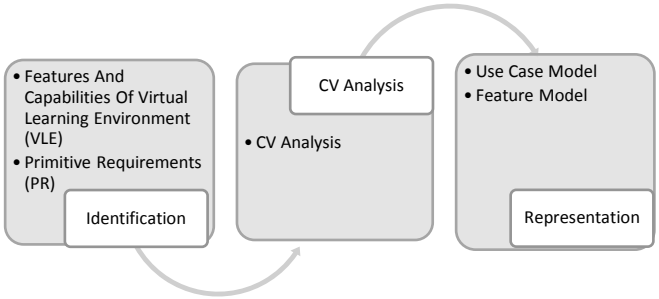

Figure 2: Approach for Identification and Representation of Requirements

PRs for related applications in a domain are identified after perform the comparison analysis on online learning platform based on constructivist learning environment. This comparison is to determine an online learning features used for top 10 VLE. Results show all features available in most of the VLE, and then it will be used as a PR for the next analysis.

The PR is then analyzed using CV Analysis in order to identify the common and optional PR. It represented using PR-Context Matrix where all the identified PRs are listed in rows and systems from the domain arranged in columns. Then, to obtain the CV properties, label "√" has been used at the intersection of PR_i and $System_j$ indicates the the PR_i is found in $System_j$. An "-" indicates that $System_j$ does not have the PR_i.

This analysis will lead to the use case model that shows << extend >> and << include >> relationship to illustrate the common and variable use case.

VII. Results and Discussion

There are 20 Primitive Requirements (PR) that has been identified on three online learning types based on the analysis in Part V. Table 2 shows PR-Context matrix of an online learning, where the identified PRs are listed in the first column and the names of Malaysian higher education are listed in the first row. CV Analysis was performed on a PR to identify the common and variable PR.

The frequency in each application of online learning is used to determine whether the PR reusable. Frequency calculated as the ratio of the total number of times the PR system. The threshold is 50%, which means a ratio with values higher than the threshold, is the PR which is used by all systems, labeled C'. If the ratio is lower than the threshold, PR considered optional represented by P. [9].

PRs are clearly divided into two categories, common and optional where 9 of them are common and 11 are optional, as shown in Table 2. PR7, PR10, PR12, PR13, PR14 and PR18 were categorized as optional because their commonality ratios were low. PR4, PR8, PR9, PR19 and PR20 were optional because the PR was not used in this three higher education online learning application.

Table 2
Online Learning Domain: PR-Context matrix

PR No.	PR	Property	Ratio (100%)	Context		
				UTM	OUM	KKPG
PR1	Log In	C	100	√	√	√
PR2	Log Out	C	100	√	√	√
PR3	Update Profile	C	100	√	√	√
PR4	Self-paced	P	0	√	-	-
PR5	Facilitated/ instructor-led	C	100	√	√	√
PR6	Simple Learning Resources	C	100	√	√	√
PR7	Interactive e-Lessons	C	66.7	√	√	-
PR8	Electronic simulations	P	0	-	-	-
PR9	Job aids	P	0	-	-	-
PR10	E-tutoring	C	66.7	√	√	-
PR11	Online discussions	C	100	√	√	√
PR12	Collaboration	P	33.3	√	-	-
PR13	Virtual Classroom	C	66.7	√	√	-
PR14	Synchronous e-learning activities	C	66.7	√	√	-
PR15	Asynchronous e-learning activities	C	100	√	√	√
PR16	Programme flow model	C	100	√	√	√
PR17	Core-and-spoke model	C	100	√	√	√
PR18	Quiz tests	P	33.3	√	-	-
PR19	Self-assessment	P	0	-	-	-
PR20	Peer assessment	P	33.3	√	-	-

Since PR is a transaction which affects actors, PR is then associated with the use case that has been set as shown in Table 3. From the table it can be shown that each use case can be attributed with optional or common PR. Next, we constructed a domain use case model in Figure 3. An optional PR can be refine into a use case with an <<extend>> relationships. For example, from the use case Manage Components, 3 optional PR that are E-tutoring, Collaboration and Virtual Classroom were connected to Manage Components by <<extend>> relationships. 1 common PR, Online Discussion was connected to Manage Components by <<include>> relationship.

Table 3
PRs associated with use case

Reg. ID.	PR	CV	(UC1) User Authentication	(UC2) Manage user	(UC3) Manage approaches	(UC4) Manage contents	(UC5) Manage Component	(UC6) Create Learning Activities	(UC7) Implement Blended Learning	(UC8) Manage Evaluation
PR1	Log In	C	√							
PR2	Log Out	C	√							
PR3	Update Profile	C		√						
PR4	Self-paced	P			√	√		√		
PR5	Facilitated/instructor-led	C			√	√		√		
PR6	Simple Learning Resources	C				√				
PR7	Interactive e-Lessons	C				√				
PR8	Electronic simulations	P				√				
PR9	Job aids	P				√				
PR10	E-tutoring	C					√	√		
PR11	Online discussions	C					√	√		
PR12	Collaboration	P					√	√		
PR13	Virtual Classroom	C					√	√		
PR14	Synchronous e-learning activities	C						√		
PR15	Asynchronous e-learning activities	C						√		
PR16	Programme flow model	C							√	
PR17	Core-and-spoke model	C							√	
PR18	Quiz tests	P								√
PR19	Self-assessment	P								√
PR20	Peer assessment	P								√

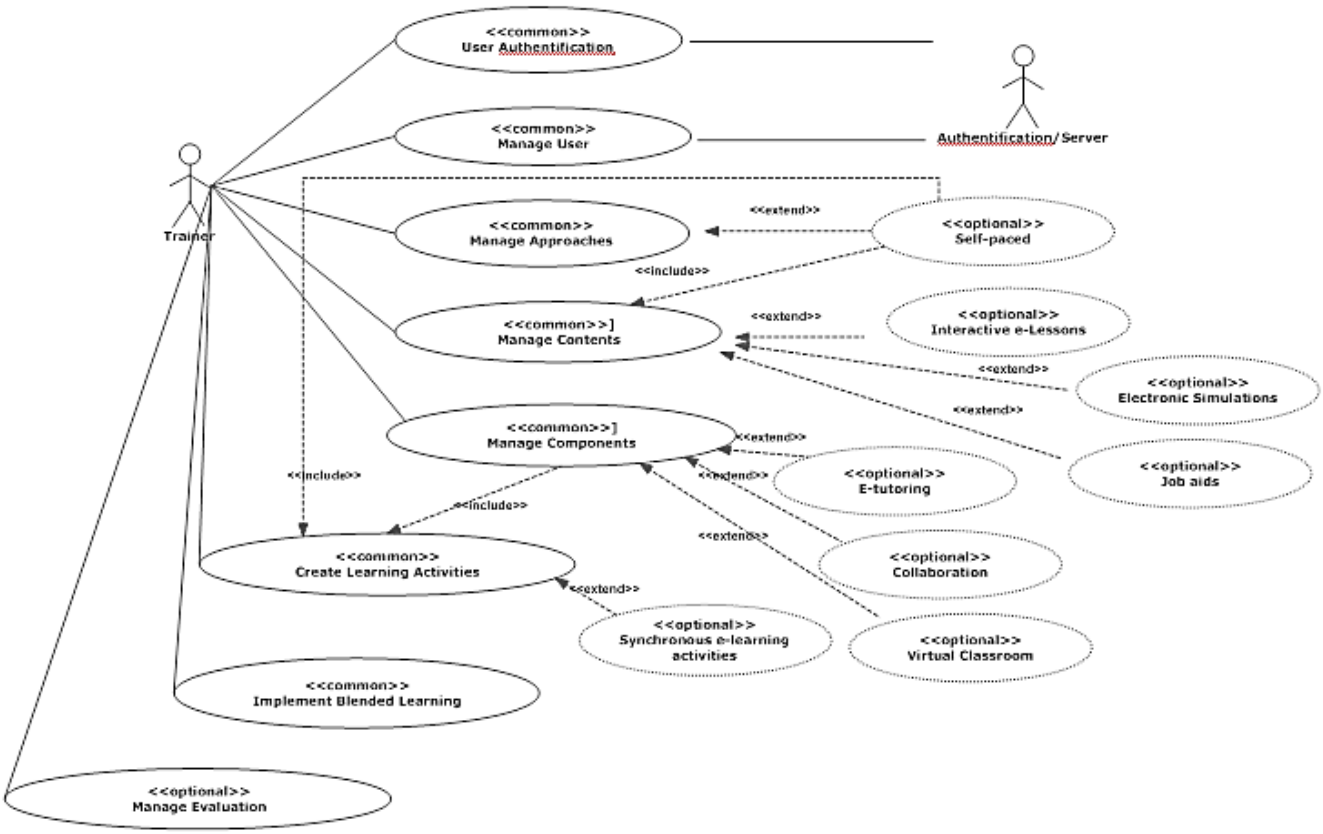

Figure 3: Use Case Domain Model for Online Learning Product Line

VIII. CONCLUSION

The problem of developing educational software is not new. When technology developed is inadequate for both teachers and learners [4], it needs labor intensive process to produce and maintain educational technologies due to its huge size. However, the complexity and effort needed to produce and preserve learning technologies can be minimized with SPL approach. Practically, SPL requires no cost since the process is performed automatically. The process is

executed by computer, thus it is capable to avoid human mistakes, assure product quality and reduce cost associated to fixing human mistake.

Variability management is a key activity that affects the extent to which the SPL is successful. This study focuses on core asset to identify and represent the commonalities and variability in variability management. In CV Analysis, PRs are identified and analyzed to determine its commonality or variability status and associated with suitable use case. The purpose of this study is to develop a feature model which further helps in visual representation variants requirements and enhance reusability in the context of product line approaches. The identification and representation will increase the potential for reuse and help in publishing the specific requirements of the application in the development of the product line.

This approach has been used in online learning product line of higher learning in Malaysia and it can benefit from the visibility and reuse of requirements. For future work, it is suggested to further enhance the feature model to support knowledge-rich approaches that can be combined with other approaches to enhance their expressiveness.

ACKNOWLEDGMENT

Our deepest gratitude to the Ministry of Education (MOE) for their financial support in this study.

REFERENCES

[1] E. Sustainable, "Online Education, Teaching, and Learning - Part One," *Online*, pp. 70.

[2] P. S. Barreiro, D. García-Saiz, and M. E. Z. Pantaleón, "Building families of software products for e-Learning platforms: A case study," *Rev. Iberoam. Tecnol. del Aprendiz.*, vol. 9, no. 2, pp. 64–71, 2014.

[3] S. Chimalakonda and K. V. Nori, "Accelerating educational technologies using software product lines," in *2012 IEEE International Conference on Technology Enhanced Education (ICTEE)*, 2012, pp. 1–4.

[4] D. L. Dalmon, L. O. Brandão, A. A. F. Brandão, and S. Isotani, "A domain engineering for interactive learning modules," *J. Res. Pract. Inf. Technol.*, vol. 44, no. 3, pp. 309–330, 2012.

[5] S. Chimalakonda and K. V. Nori, "What makes it hard to apply software product lines to educational technologies?," in *2013 4th Int. Work. Prod. LinE Approaches Softw. Eng. PLEASE 2013 - Proc.*, 2013, pp. 17–20.

[6] A. Guendouz, "Customer satisfaction through e-learning software product line," in *The Ninth International Conference on Internet and Web Applications and Services*, 2014, pp. 14–18.

[7] S. Pablo, D. Garc, M. Zorrilla, and D. Matem, "Software product line engineering for e-learning applications : A case study," in *Proc. 2012 Int. Symp. Comput. Educ.*, 2012, pp. 1–6.

[8] f. ahmed and i. zualkernan, "a software product line methodology for development of e-learning system," *Int. J. Comput. Sci. Emerg. Technol.*, vol. 2, no. 2, pp. 285–295, 2011.

[9] M. Moon, K. Yeom, and H. S. Chae, "An approach to developing domain requirements as a core asset based on commonality and variability analysis in a product line," *IEEE Trans. Softw. Eng.*, vol. 31, no. 7, pp. 551–569, 2005.

[10] S. A. Halim, D. N. A. Jawawi, and S. Deris, "Requirements identification and representation in software product line," in *Proc. Asia-Pacific Softw. Eng. Conf. APSEC*, 2009, pp. 340–346.

[11] A. Guendouz and D. Bennouar, "A Software Product Line for Elearning Applications," in *The International Arab Conference on Information Technology (ACIT'2013)*, 2013, pp. 1-6.

[12] R. Capilla, J. Bosch, and K.-C. Kang, *Systems and Software Variability Management*. Springer-Verlag Berlin Heidelberg, 2013.

[13] P. Trafford and Y. Shirota, "An introduction to virtual learning environments," *Gakushuin Econ. Pap.*, vol. 48, no. 10, pp. 143–151, 2011.

[14] A. S. Al-Ajlan, *A Comparative Study Between E-Learning Features*. InTechOpen, 2012, Ch. 10.