CoMa: Development of Gamification-based E-learning

Fitra A. Bachtiar*, Fajar Pradana*, Bayu Priyambadha*, and Dhanuari I. Bastari

*Faculty of Computer Science**

Brawijaya University, Malang

Email: fitra.bachtiar@ub.ac.id, fajar.pradana@ub.ac.id, bayu_priyambadha@ub.ac.id, d.indrabastari@gmail.com

Abstract—There has been evidence that many of e-learning implementations fail to achieve their learning objectives due to incompatibility and lack of knowledge in developing an online information system. This failure could lead to frustration, confusion, and a decrease in the student engagement in learning. Moreover, transferring physical materials to the digital ones could result in boredom because there is no interactivity in the learning process. As a consequence, student engagement in learning decreases. Gamification concept may be used to increase student engagement in learning. This study develops an e-learning system by adding gamification concept. Gamification elements used in this study are leaderboard, activity point, experience point, badge, challenges, leveling, and add friends. The e-learning system is implemented in the Java Programming course. This e-learning is called Code Mania (CoMa). The e-learning is a web-based system that allows the user to interact easily. The e-learning also has an automatic evaluation feature to evaluate student work. The developed learning system is evaluated using whitebox testing that is path testing and blackbox testing. The result from the testing shows that the e-learning system could run well as specified in the system requirement.

Index Terms—e-learning, gamification, software engineering education, java, programming

I. INTRODUCTION

Nowadays the need for teaching and learning activities have shifted from conventional to innovative learning that involves technology [1]. This situation is shown by the considerable adoption of learning media and the use of technology by many institutions [2]. The shifting from conventional learning to one using technology cannot be separated from the development of the Internet technology [3] and multimedia [4]. One of the drives of transformation in learning using technology is the need of speedy access of information, personalization, flexibility, portability, and on-demand manner [1]. Teaching and learning using technology, especially web technology, is very popular as the technology offers flexibility where users could access information from the Internet directly [5]. The use of technology in the teaching and learning environment using web technology is called e-learning [6].

E-learning that is growing at the moment refers to student based learning where the teaching and learning activities are focused on autonomous activities. Student-based learning is a learning where the activity is centered on students [7]. In addition, in student-based learning puts more emphases on students' responsibility during the teaching and learning activities [8]. This learning model is emphasized on the mastery of skills and activities that enable students to empower themselves to have problem-solving capacities. Furthermore, this model of learning also places students' interest as priority during the learning activities

However, many of the applications of e-learning which are essentially student-based learning do not yet reach the objectives successfully [9]. One reason is the facilitators' lack of knowledge and skills as well as the appropriateness of their knowledge on the techniques to develop online information systems, and other problems [9]. E-learning users that are demanded to be autonomous during their learning on the e-learning system may face a number of challenges. Previous studies reveal e-learning modes that inappropriate deployment of e-learning modes lead to frustration, confusion, and lowering students' interest in learning [10][11]. In addition to that, e-learning also lacks interactivity between students and teachers as face-to-face teaching modes [12]. Migration of instructional materials from physical forms to digital ones could cause a boredom problem as there is no interactivity from the learning material aspect [13]. Moreover, some students might not be comfortable or suitable using e-learning. One way to overcome interactivity problem is to motivate and to engage students in e-learning by providing them with interactive and engaging e-learning.

One possible solution to enhance students' interest in learning is by applying gamification concept. Gamification is the use of game design element that is applied in the non-game context [14]. Another definition of gamification stated that the use of philosophy, element, and mechanics from game designs in the non-game context to introduce or trigger specific behaviors to the user and to enhance motivation and engagement in performing particular tasks [15]. Gamification has been applied in various domains. One of the gamification application is in the educational domain to increase student motivation, interest, and performance in learning [16].

There are typical elements that are generally used in the research in application development based on gamification context. There are much research, specifically in the application of gamification, focusing on relatively easy game mechanics such as point, badges, leaderboard, and level. A study was conducted by Topirceanu [13] using many gamification elements that is heroes integration, grade, level, accumulated experience, level-ups, guilds, quests, achievement, and other representation types in role-playing games.

In this research gamification concept is applied to develop an e-learning system. The e-learning based gamification is designed specifically for learning Java programming language. The gamification element used in this study is leaderboard, activity point, experience point, badge, challenges, add friends and leveling.

II. E-LEARNING

There are many definitions of e-learning. E-learning is information technology and communication that is used to support students to enhance their learning [17]. According to Olasfsen and Centindamar [18] e-learning is defined as the capability of a system to transfer electronically, manage, support, and supervise learning and learning materials. E-learning also is also referred to the use of internet technology to send a series of solution that can be used to increase students knowledge and skills [19]. Meanwhile, in other definition e-learning is defined as teaching and learning activities where the delivery of the learning materials uses the Internet or computer network [20]. Based on the various definition from the previous researcher, e-learning can be summarized as information technology that is used for learning purposes where students could perform learning activities where the learning can be accessed through the Internet media or local network.

III. GAMIFICATION

A. Definition

Gamification is a process of using mechanism and game design technique applied to the non-game context [14]. The purpose of gamification is to increase student engagement [21] and motivation to reach a specific purpose [22]. According to Caponetto et al. [23], gamification is a way to implement an appropriate game concept that results in an enjoyable and useful process to all users involved.

B. Gamification elements

There are various types of gamification elements that are commonly used that are point, user level, achievement, and challenge [14].

Point is a value owned by the user. Point owned by the user could increase if the user performs learning activities in the developed gamification e-learning. The point system is also known as Experience Point (EXP). The EXP is used by the user to access another set of features in the gamification e-learning. The features in the gamification e-learning can be accessed if the user has reached a specific EXP.

User level is a social status owned by the user in gamification e-learning. The user could obtain a point if the user is able to finished tasks, accessing the learning material and performing certain activities such as adding another user as friends in the system. User level will increase if the user is able to get accumulated points that have reached specific values. User level can be used to create a competition among users as the user level information can be seen by another user in the system. The users might compete for one another to reach the highest level.

Achievement is a part of gamification elements used to give an award to users with specific goals and specific requirements. Each achievement has different requirements depending on the objectives or goals that will be attained in the learning. Achievement is given if user has finished specific tasks.

Challenge is a gamification mechanism that allows the user to challenge another user in solving a problem. Users that have the same level are able to challenge another friend in the friend lists to solve a specified problem in the system.

IV. APPLICATION TESTING

Software testing is the last step in developing a system. The objectives of the software testing are to find mistakes in the development of software [24]. There is two software testing that is generally used that is whitebox testing and blackbox testing.

A. Whitebox testing

Whitebox testing is a testing technique that is performed in the code, program, or algorithm with the objective to find mistakes in the code, program, or algorithm. One of whitebox testing that is generally used is base path testing [25]. Base path testing aims to determine cyclomatic complexity in a code, program, or algorithm [24]. There are four testing elements in the base testing that is flow graph, cyclomatic complexity, independent path, and test case. Flow graph explains logical structure of a code that creates a program flow. An example of flow graph is shown in Figure 1 where Region (R) denotes the region in the process, V(G) denotes the number of region in the flow graph, Edge (E) denotes the connecting process, Node (N) denotes the process, and P (Predicate Nodes) denotes the process from the previous step.
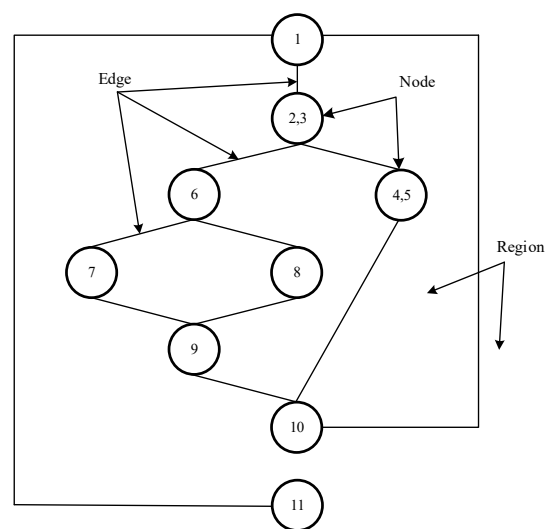

Fig. 1. Flowgraph example [24]

Cyclomatic complexity is a measure that is used to understand the logical complexity in a code or program. There are three ways to calculate cyclomatic complexity V(G):

1) V(G) = number of region in the flow graph

2) V(G) = E (Edge) N (Node) + 2

3) V(G) = P (Predicate Node) + 1

Independent path is are all path traversed by a code or program to produce a new result or condition. Meanwhile, test case is an input used to check logic flow or condition in each independent path. Independent path is used as a base path in the execution testing process. The cyclomatic complexity value in the code or program according to Software Engineering Institute [26] are explained in Table I.

TABLE I
CYCLOMATIC COMPLEXITY VALUE DESCRIPTION

Cyclomatic complexity	Meaning
1-10	Code or program can be understood easily, easier to fix, easier to test, and low-risk program error.
11-20	Program is more complex, testing is more difficult, and moderate risk program error.
21-50	Program is very complex, testing needs more effort since there are a lot of execution path program, and high-risk program error.

B. Blackbox testing

Blackbox testing is testing that involves output observation from specific input value. Blackbox testing is not intended to analyze program code and more focuses on a function or software behavior. In principle, blackbox testing is conducted to observe the result of system response after a specific stimulus is given [27]. Functional testing is one of blackbox testing that generally used.

V. COMA: GAMIFICATION BASED E-LEARNING

E-learning is developed through several steps that is literature study, requirement analysis, system design, implementation, and software testing. Waterfall method with SDLC approach is used to develop the system. An overview of the steps to develop gamification e-learning is shown in Figure 2.

A. Literature review

Literature review from previous study is conducted to list gamification elements commonly used to enhance student engagement in learning. In addition, literature review is performed to understand and to apply software design and development. Literature review is also conducted to decide which software testing to use.

B. Requirement analysis

The gamification e-learning developed in this research is intended to create a web-based system for Java programming learning. The system is developed to enhance student engagement in learning programming. A student could learn programming material through text and figure information. In addition, the student can also work on exercise from the available learning material. The developed system also have challenge feature that allows user or student to challenge
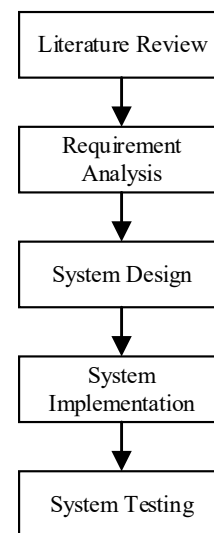
Fig. 2. CoMa development

another student to work on a set of programming problem. A point will be awarded to user or student if the student succeed to accomplished the tasks.

Actor identification

TABLE II
ACTORS INDENTIFICATION

Actor	Description
User	User has to login to the system to authenticate role of the user.
Admin	Admin has the capability to manage users' data, learning material, achievement, and questions.
Member	Member is able to access the learning material, achievement, working on exercise, find another member, add another user as friend, and challenge another member.

Elicitation and requirement specification

Code analysis and requirement specification are needed for system development to be easily tracked. Code analysis and requirement specification code is shown in Figure 3. "CM" refers to developed system that is CoMa, "X" is the types of type actor requirements, and "00" is the number of requirement based on the actor.

$$CM - X - 001$$

Fig. 3. Requirement rule numbering

From the analysis result, there are two user functional requirements, 24 admin functional requirements, and 18 member functional requirements. An example of each of user requirements can be seen in Table III.

TABLE III
ACTORS IDENTIFICATION

No	Actor	Function	Description
1	CM-1-001	Member login	User has to login to get authorization as member
2	CM-2-003	Modify achievement	This feature is used t modify achievement received by a member
3	CM-3-002	View exercise history	This feature is used to view a list of all exercise have been done by all members

Use case diagram modeling

Use-case diagram is used to model business process based on users' perspective. Business process consists of behavior and actor acting in the system. Figure 4 and Figure 5 shows Use-case diagram of each actor that could interact with the system.
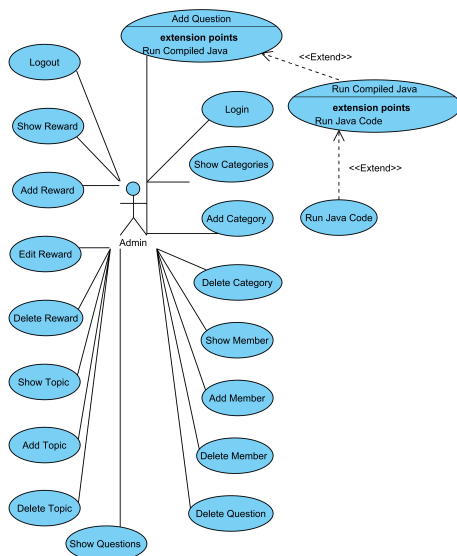
Fig. 4. Use-Case diagram admin

Fig. 5. Use-Case diagram user and member

C. System Design

System design in this study is divided into two main steps that are software design and interface design. Software design is decomposed into three steps that is architecture design, component design, and database design.

Software design

The software design related to designing the whole system such that the system could be well organized. The result of the architecture design is class diagram which created based on object identification in the sequence diagram. Figure 6 shows the sequence diagram of run compiled code.

Admin actor performs three activities that are entry data parameters, setting random testing, and press test code. Those activities are done in boundary :question edit. Then testJava method is invoked. This invocation also triggers random value
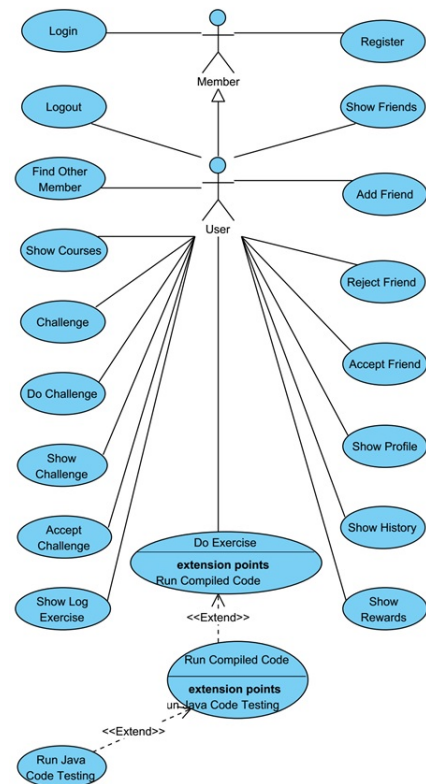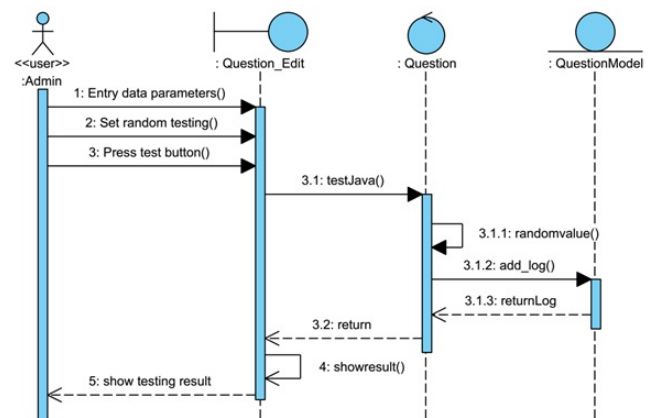
Fig. 6. Sequence diagram of run compiled code

method. Activity log will be saved by executing addlog method in the :questionmodel entity. The return value is a log that will be displayed on the boundary.

Component design

The component design is a decomposition of a sub-system into detailed components. Component design explains about attribute and algorithm method in a class that has been modeled before in the Class diagram process.

User interface design

User interface design is conducted to map how the user will interact with gamification e-learning. There are several interface design in the CoMa e-learning. Figure 7 shows the interface design of the main page in the e-learning system.
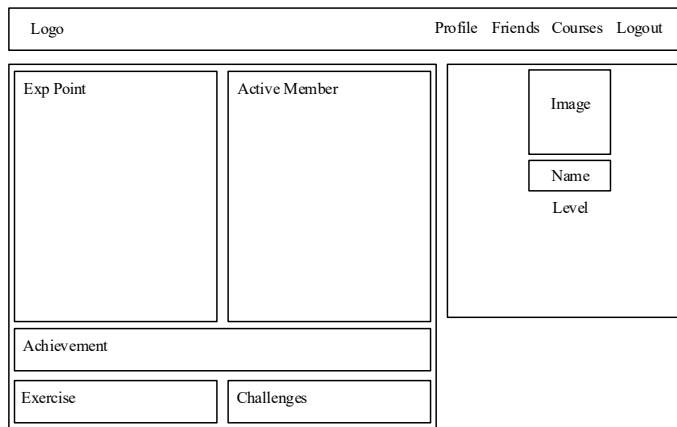

Fig. 7. Main page interface design

Fig. 8. Main page interface implementation

Fig. 9. Challange feature implementation

D. Implementation

The next step of the e-learning development is implementation. This step is implementing the system design in the previous steps. The implementation is based on software design that consists of architecture design, component design, database design, and interface design. The e-learning is implemented using PHP programming language.

E. System testing

Two methods is used to validate the developed system. Unit testing and validation testing is used as the testing method. The first testing is unit testing. Unit testing is performed using base path testing that will model the pseudocode in the flow graph form. The testing unit is conducted to determine the cyclomatic complexity and independent path. The second testing is validation testing. Validation testing ensures all of the system functional requirement running as expected by the user. The method used in this testing is blackbox testing method.

VI. RESULTS

A. Implementation results

The system based on the design is implemented and tested using whitebox and blackbox testing. The implementation result from the design is class implementation, algorithm implementation, database implementation, and interface implementation.

Example of interface design implementation in the design steps is shown in Figure 8 and Figure 9. Figure 8 is an example of the main page interface implementation CoMa e-learning. Meanwhile, Figure 9 is an interface implementation of challenge another user to solve a programming problem.
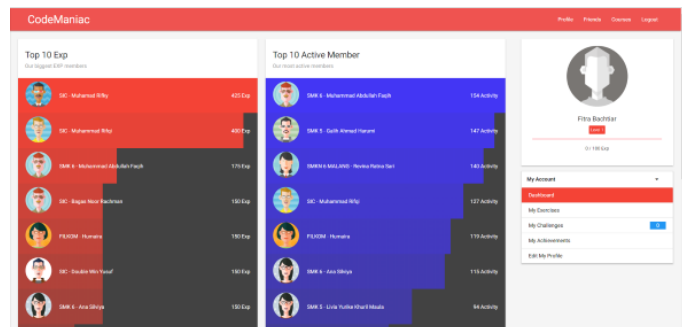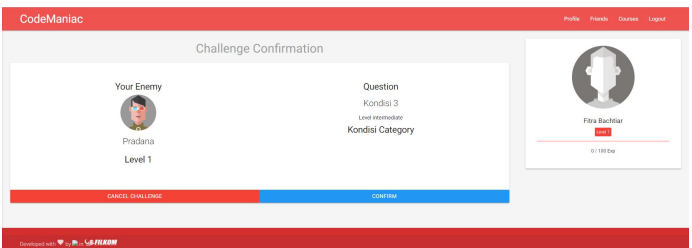
B. Testing results

The result of system testing using unit testing method is shown in Table IV. Testing is conducted in three e-learning method that is obtaining experience point, displaying achievement, and performing challenge. These three methods are taken randomly from the method that related to gamification elements.

TABLE IV
UNIT TESTING RESULTS

Method	R	N	E	P	VG	Status
Obtaining experience point	4	9	11	3	4	Valid
Displaying achievement	3	6	7	2	3	Valid
Performing challange	3	9	10	3	3	Valid

The result of validation testing can be seen in Table V. Validation testing is done using blackbox testing. The validation is performed to make sure all system functional requirements runs as expected. Three methods are tested in the system that is obtaining experience point, displaying achievement, performing challenges.

The implementation and testing result shows that the developed system runs according to the design which defined in the previous steps.

VII. CONCLUSION

Improper e-learning system development may impact on the ineffective learning process. Creating a simple E-learning by transferring physical content to digital ones may influence student motivation and engagement in using e-learning. Moreover, there are differences in the learning process in conven-

TABLE V
VALIDATION TESTING RESULTS

Method	Expected result	Status
Obtaining experience point	System provide the experience point according to the performed exercise or task. User will obtain 25 points for easy task, 50 points for moderate task, and 100 for difficult task.	Valid
Displaying achievement	System display user achievement in the dashboard.	Valid
Performing challenge	System constrained challenge between member with the same level and provide experience point according to exercise or task difficulty.	Valid

tional learning and using e-learning in which the e-learning context is lacking interactivity. Therefore, consideration should put into account to increase student interactivity in e-learning using gamification concept in developing an e-learning. The objective of this study is to develop an e-learning system by adding gamification concept. The gamification concept used in this study is leaderboard, activity point, experience point, bade, challenge, leveling, and add friends. Java programming learning is used as the study case in this research. Waterfall method with SDLC approach is used to develop the system. The developed system is then validated using two testing method. The testing method used is whitebox testing that is path testing and blackbox testing that is validation testing. The result of the two testing shows that the developed system is valid.

This study is conducted to develop an e-learning system and applying gamification concept to increase student interactivity, motivation and student engagement using e-learning. Hopefully by using this system student could have more enjoyable and fun learning.

This study is in the early stage development and there are a lots of enhancement could be done further. A direction to consider in more depth for similar system is to add another gamification concept in the e-learning such as prompt quizzes, challenge yourself, and time trial tasks. Also, the developed system has limitation in the material and exercise can be worked by the student. Furthermore, the usability of the system is not yet known. Further study should examine the system usability for a better user experience in using e-learning. Other consideration in similar research may study the impact of the positioning of gamification element and e-learning element as the optimal position will make the student comfortable an in turn it could increase student satisfaction in using the system.

REFERENCES

[1] D. Zhang, J. L. Zhao, L. Zhou, and J. F. Nunamaker Jr, "Can e-learning replace classroom learning?" *Communications of the ACM*, vol. 47, no. 5, pp. 75–79, 2004.

[2] E. W. Ngai, J. Poon, and Y. H. Chan, "Empirical examination of the adoption of webct using tam," *Computers & education*, vol. 48, no. 2, pp. 250–267, 2007.

[3] A. Popovici and C. Mironov, "Students perception on using elearning technologies," *Procedia-Social and Behavioral Sciences*, vol. 180, pp. 1514–1519, 2015.

[4] S. Hubackova, "History and perspectives of elearning," *Procedia-Social and Behavioral Sciences*, vol. 191, pp. 1187–1190, 2015.

[5] A. Zamfiroiu and C. Sbora, "Statistical analysis of the behavior for mobile e-learning," *Procedia Economics and Finance*, vol. 10, pp. 237–243, 2014.

[6] P.-C. Sun, R. J. Tsai, G. Finger, Y.-Y. Chen, and D. Yeh, "What drives a successful e-learning? an empirical investigation of the critical factors influencing learner satisfaction," *Computers & education*, vol. 50, no. 4, pp. 1183–1202, 2008.

[7] L. Jones, *The student-centered classroom*. Cambridge University Press Cambridge, 2007.

[8] S. Pedersen and M. Liu, "Teachers beliefs about issues in the implementation of a student-centered learning environment," *Educational Technology Research and Development*, vol. 51, no. 2, p. 57, 2003.

[9] M. Urh, G. Vukovic, E. Jereb *et al.*, "The model for introduction of gamification into e-learning in higher education," *Procedia-Social and Behavioral Sciences*, vol. 197, pp. 388–397, 2015.

[10] R. H. Maki, W. S. Maki, M. Patterson, and P. D. Whittaker, "Evaluation of a web-based introductory psychology course: I. learning and satisfaction in on-line versus lecture courses," *Behavior research methods, instruments, & computers*, vol. 32, no. 2, pp. 230–239, 2000.

[11] H. Noriko and R. Kling, "Students distress with a web-based distance education course: An ethnographic study of participants' experiences," *Turkish Online Journal of Distance Education*, vol. 4, no. 2, 2003.

[12] K. Fry, "E-learning markets and providers: some issues and prospects," *Education+ Training*, vol. 43, no. 4/5, pp. 233–239, 2001.

[13] A. Topîrceanu, "Gamified learning: A role-playing approach to increase student in-class motivation," *Procedia Computer Science*, vol. 112, pp. 41–50, 2017.

[14] S. Deterding, D. Dixon, R. Khaled, and L. Nacke, "From game design elements to gamefulness: defining gamification," in *Proceedings of the 15th international academic MindTrek conference: Envisioning future media environments*. ACM, 2011, pp. 9–15.

[15] O. Pedreira, F. García, N. Brisaboa, and M. Piattini, "Gamification in software engineering–a systematic mapping," *Information and Software Technology*, vol. 57, pp. 157–168, 2015.

[16] K. M. Kapp, *The Gamification of Training: Game-Based Methods and Strategies for Learning and Instruction*. Pfeiffer [Imprint], 2012.

[17] H. E. F. C. for England. (2005) Hefce strategy for elearning. bristol: Hefce. [Online]. Available: http://www.hefce.ac.uk/pubs/hefce/2005/05 12/

[18] R. N. Olafsen and D. Cetindamar, "E-learning in a competitive firm setting," *Innovations in Education and Teaching International*, vol. 42, no. 4, pp. 325–335, 2005.

[19] M. J. Rosenberg, *E-learning: Strategies for delivering knowledge in the digital age*. McGraw-Hill New York, 2001, vol. 3.

[20] D. E. Hartley, *Selling e-learning*. American Society for Training and Development, 2006.

[21] C. I. Muntean, "Raising engagement in e-learning through gamification," in *Proc. 6th International Conference on Virtual Learning ICVL*, vol. 1. sn, 2011.

[22] R. Khaled, "Its not just whether you win or lose: Thoughts on gamification and culture," in *Proceedings of the 2011 Annual Conference on Human Factors in Computing Systems*. Association for Computing Machinery, 2011.

[23] I. Caponetto, J. Earp, and M. Ott, "Gamification and education: A literature review," in *European Conference on Games Based Learning*, vol. 1. Academic Conferences International Limited, 2014, p. 50.

[24] R. S. Pressman, *Software engineering: a practitioner's approach*. McGraw-Hill, 2010.

[25] T. J. McCabe, "A complexity measure," *IEEE Transactions on software Engineering*, no. 4, pp. 308–320, 1976.

[26] M. Bray, K. Brune, D. A. Fisher, J. Foreman, and M. Gerken, "C4 software technology reference guide-a prototype." Carnegie-Mellon Univ Pittsburgh Pa Software Engineering Inst, Tech. Rep., 1997.

[27] R. S. Pressman, *Software Engineering : A Practitioner's Approach*, 7th ed. McGraw-Hill, 2015.