Mobile Learning: Visualizing Contents Media of Data Structures Course in Mobile Networks

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***Abstract*—The utilisation of mobile learning in teaching brings the benefits of the availability of teaching materials that can be accessed at any time and exciting material visualisation. In its implementation, it needs the availability of supporting devices, such as network availability, smartphone devices, and mobile learning software. The paper examines the availability of mobile networks and also develops mobile learning software. The app is then implemented directly in the mobile networks, performing measurement and performance testing on the parameter which is the quality of service metrics by internet service providers in locations of the research project. Based on the measurement and application testing, the planning and development of mobile learning should focus on the usability factors, such as the ease for network access, user-friendliness, and the ease to comprehend the teaching materials. Other than that, the amount of data used when accessing the app is also monitored. The presentation of the teaching materials is made more straightforward, attractive, and interactive. The failure of mobile learning applications during testing is generally due to the problem of network availability. The development of mobile learning app must be adapted to the capabilities of the existing network performance.**

***Index Terms*—Mobile-learning; Performance; Network; Data-structure; Media.**

I. INTRODUCTION

Learning problems in the data structures course have always been the topic of discussion among lecturers in computer science [1] because this course has a high number of failures [2-3]. The lecturers have used various approaches, methods, strategies, patterns, and technologies, but there has been no appropriate solution to be applied [4].

Different levels of acceptance, understanding or learning capacity for each student are a challenge for lecturers. The failure to learn the course data structure for students occurs because this course requires abstract thinking [5]. Many theories require research and deep understanding. Also, the density of teaching materials and its contents and methods are different from one subject to another. This requires high thinking skills in order to understand and learn the data structures course [4-6].

Many teaching approaches have been carried out by lecturers [7]. The approach compares CDIO teaching with traditional teaching to determine the effectiveness of CDIO teaching. CDIO model combines theoretical and practical project knowledge to improve students' theoretical and innovative abilities [8].

In [9], the system is implemented with the gamification concepts - like points, levels, and leaderboards, to motivate students in the learning process and stimulate self-learning. The system includes basic concepts taught in this discipline as stacks, queues, lists, arrays, trees, and it was implemented to receive new ones.

Data Structures is a course that combines theory with practice. Students are not only required to possess a solid foundation of higher mathematics and data structures, but also a strong ability for abstract thinking and computer programming. The traditional teaching of data structures pays most attention to mathematical reasoning, proving correctness and the complexity analysis of algorithms.

The study of a literature review on tools for learning data structures [4] describes mobile learning approach that utilises smartphone devices as a tool in the instructional media and visualises the contents of teaching materials for easy understanding.

Both approaches of this method of teaching are considered to be able to support and improve student learning outcomes; they can be used as a tool for teaching without time limit. It is the first step in building a learning paradigm that can be done anywhere and anytime.

Based on the experiences and references from literature studies [1-9], the authors are interested in developing a visual learning media for the data structures course, with the model framework and presentation of the material that focuses on the visualisation of teaching contents, which utilises mobile technology and students' smartphones.

Also, this paper also performs testing and performance measurement of the mobile learning applications to ensure the availability and capabilities of mobile networks.

In particular, the aim of the paper is the mobile learning development in data structures course for 2nd-year students in the Dept. of Informatics Mulawarman University. Thus, the objectives are to:

- design an instructional framework that focuses on the visualisation of content media theory-practice of data structures course, and
- evaluate performance, and capabilities of learning media app in mobile networks with network availability testing including the speed test, and Quality of Service testing.

II. LITERATURE REVIEW

A. A Review of Research on Mobile Learning

Mobile technologies, such as smartphones, tablets, and laptops, as well as online applications, networking, the internet, and tools [10-12], are becoming an integral part of the lives of most teachers and students in East Borneo.

Survey results [13] in Figure 1 show that there were 132,711,511 data internet users in Indonesia in 2016, and

about 5.8% or 7,685,992 users in Kalimantan. The most frequently used type of internet service is the mobile internet with the percentage of 69.9%, i.e. 92.8 million users.

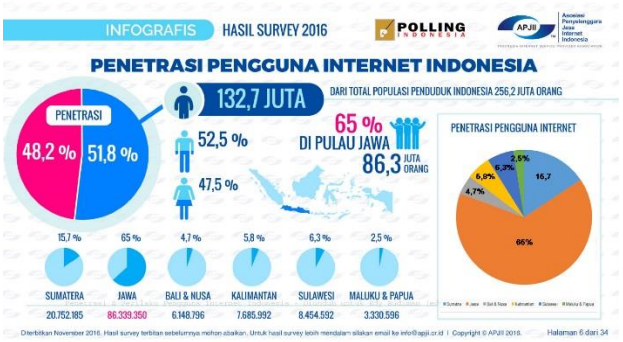

Figure 1: Penetration of Internet users in Indonesia [13]

Mobile technologies devices have transformed the way people communicate, information search and work. The challenge for the educators and researchers is to explore how mobile technologies might be used to support learning [14],[15].

In 2015, Indonesian mobile cellular users, especially in the major urban centres, adopted mobile cellular services in all walks of life including e-education [16]. Mobile devices have become an attractive learning tool for education.

Many researchers have focused on mobile learning and its environment. Some researchers have defined the difference between e-learning and mobile learning, saying that learning is a learning process which is supported by digital electronic tools and media, and by analogy, m-learning is e-learning that uses mobile devices and wireless transmission [17].

Existing research has mainly focused on the value of mobile learning for students [18] and teachers [19].

Studies on the tools for learning data structures are reviewed in [4] with reports on how researchers or computer scientists have gone about to tackle the problems faced by students in learning data structures and various approaches taken to make data structures learning more fun and productive.

This [4] literature review includes various tools, technologies, advantages of using these technologies and suggestions on the techniques that can be combined for active learning of data structures.

B. Framework for Mobile Learning

The framework for developing a mobile learning system adapts [20],[21], which explains the 5R adaptation framework, i.e. at the Right Time, in the Right Location, through the Right Device, providing the Right Contents to the Right Learner. However, this paper only examines the provision of the Right Contents. The 5R adaptation framework is presented in Figure 2.

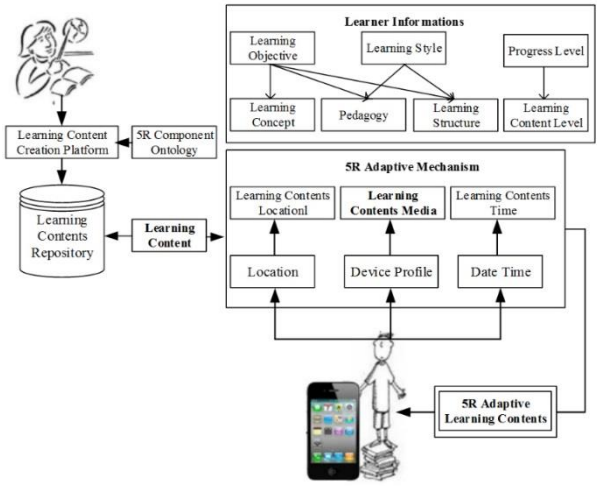

Figure 2: The 5R adaptation framework for mobile learning [20-21]

Focuses on the Right Contents, [21] describes that the contents of the adaptation framework include learning objects, learning activities, and learning instructions. The learning contents can be raw learning materials or pre-developed structured learning materials, stored in the learning contents repository of the learning management system.

The learning contents can be constructed or retrieved based on the learning objectives and outcomes, pedagogy, and structure. The right learning contents will suit the learner's learning objectives and learning styles, the particular time and location as well as the mobile device that is used by the learner to conduct mobile learning [21].

C. Data Structures Course

In curriculum guidelines for the Undergraduate Degree Programs in Computer Science [22] and Computer Engineering [23], the students are exposed to the fundamental concepts, terms of data structures and the skills necessary for their use in modelling real-world tasks. These are a part of the subject matter of the Fundamental Data Structures and Algorithms courses [24].

The study of data structures and algorithms provides insights into the intrinsic nature of the problem, as well as the possible solution techniques independent of programming language, programming paradigm, computer hardware, or any other implementation aspects [22].

The Data Structures course in the curriculum of ICT majors Mulawarman University is in the second-year or 3rd-semester. The syllabus and subject matter of this course can be seen in reference [25].

III. RESEARCH METHODOLOGY

A. Development of Mobile Learning App

1) Software Analysis and Design

The analysis and design of the mobile learning app utilise the object-oriented Unified Modeling Language (UML) [26]. The student's role in mobile learning is to get access to the media. The teaching subject to be packed in the media refers to the syllabus of the data structures course. Each material will be presented in three forms, i.e., theoretical (concept), code, and visual animation. The list of media contents to be presented is in Figure 3.

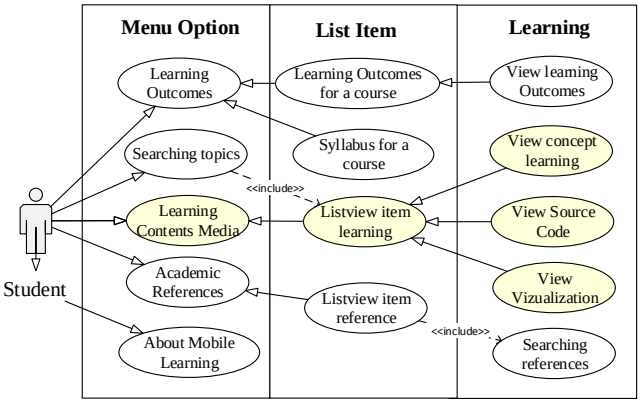

Figure 3: Use case diagram for users

B. Framework of Visual Contents Media

Mobile learning media contains teaching materials based on the syllabus of the Data Structure course. Teaching materials are visualised in the forms of texts, images, and moving animations. The media content created includes the teaching material as shown in Figure 4. It comprises the subject matter; Array, Queue, Stack, Graph, Tree, Sort, Search, and Linked List.

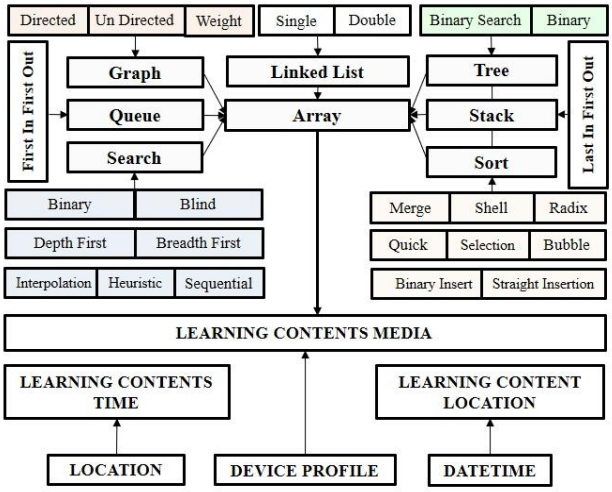

Figure 4: Framework contents media for mobile learning

C. Performance Mobile Learning in Networks

To evaluate the performance of mobile learning applications in the network, the measurement parameters [27-29] are broadband Quality of Service Experience (QOSE). Testing standard from LIRNEasia, defined a set of six performance metrics that should be measured in each experiment, as shown in Table 1.

Table 1
Metric QOSE Standard of LIRNEasia [27-29]

Metric	Method	Benchmarks
download speed (kbps)	file size 1 megabyte; time	
upload speed (kbps)	MB file	
latency: round-trip-time	The average of 10 pings	<300 ms
jitter (ms)	(each ping provides 3 sets	<50 ms
packet-Loss (in %)	of results.	<3%
availability (in %)	Availability = (1 – F/T) x 100%.	>98%

IV. ARCHITECTURE OF MOBILE LEARNING

The architectural design in the development of mobile learning system is as in Figure 5. The design is divided into three key elements that must be provided. Those elements are the availability of the network, smartphone devices, and application software.

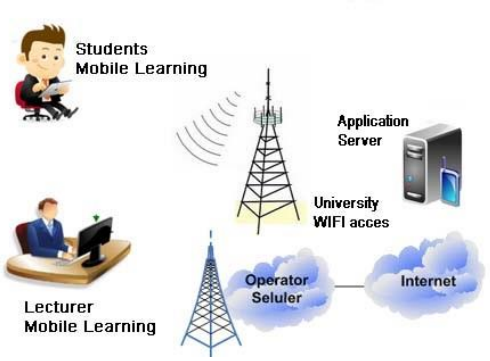

Figure 5: Network architectures for mobile learning

1) Availability of network:

The literature on the availability of mobile networks in the city of Samarinda, which became the object of research, has been researched and reviewed previously by [11]. However, related to the application of this instructional media, re-test and measuring work is done by directly implementing this media on the internet. This work is to ensure that the availability of existing networks can support and execute in accordance with expected results.

2) Smartphones Device

The number of internet users and the network connection to use mobile devices in Indonesia is very large and massive [30-32], specifically, for students in the University of Mulawarman as potential users; all students have smartphones that support mobile learning system.

3) Application Software for Mobile Learning

For the availability of software applications, we design and develop the mobile learning for the data structures course that can support the undergraduates of Degree Programs at the University of Mulawarman.

V. TESTING AND ANALYSIS

A. Development of Mobile Learning App

Implementation is the realisation of an application. In the implementation phase, the application of the mobile learning data structures course is run to see how the system was built and worked in practice.

The mobile learning app which can be installed on Android system is one of the ultimate productions for this study. It is conceived as a learning system with a base on mobile android, utilising smartphone for learning, and organising the students learning process anytime and anywhere.

In general, the contents of teaching materials of the mobile learning as a media of instruction contains material; Array, stack, queue, tree, linked list, graph, sorting and searching. Specific hierarchical content material information can be seen in the mind map diagram in Figure 6.

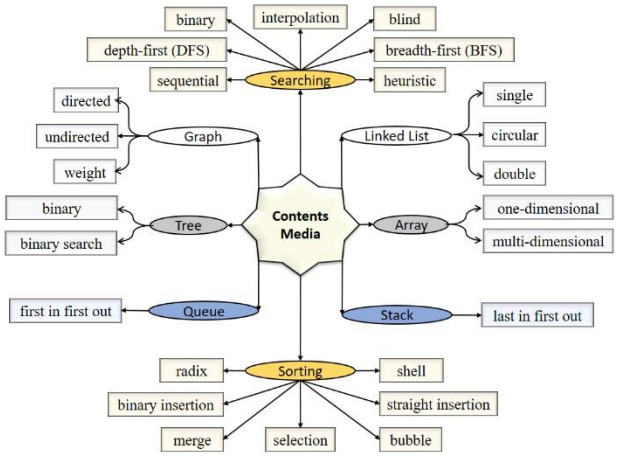

Figure 6: Mindmap diagram of contents media in data structure course app

The primary interface in the teaching module includes the material subjects of arrays, list, stack, queue, tree, sort, search, and graphs. The main menu is packed and presented in 4 menus, i.e. Learning Outcomes, Searching Topic, M-Learning, and References. The main menu for user interface displays from the mobile learning application shown in Figure 7.

Figure 7: Screenshot of the main interface and contents media mobile learning

B. Implementation Visualizing of Contents Media

This paper discusses the material teaching from the subject content media in course Data Structures, visualised in mobile learning. There are three ways of presenting in Figure 8, the contents of media materials teaching are:

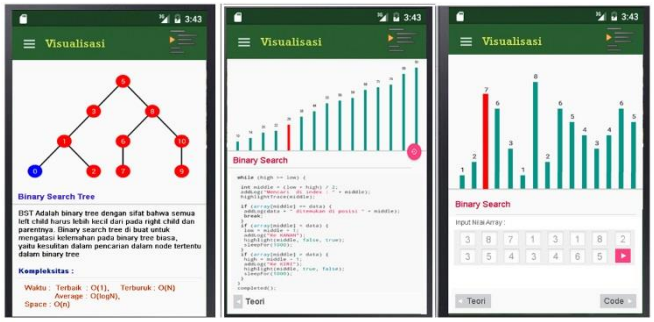

Figure 8: Screenshot for visualising of contents media

1) *Material Teaching*: *Visual of Concept/Theory*: This menu presents the concept of the material, which contains explanations of theories, definitions, complexities, procedures or steps to resolve problems, weakness and strengths, examples of implementation, and others.
2) *Material Teaching: Visual of Code:* This menu presents the material in the program code of each theoretical concepts, implemented with the programming language with simple listing coding.
3) *Material Teaching: Visual of Animation Moving*: This menu presents the material as an example of the display of the program's code running from the material in visualisation, and interactive. Students can provide value or do input in the media to see the process of each concept of teaching materials available. Visualization of this material is packaged in the form of animated moves based on input from the user system.

C. Implementation: Performance of Mobile Learning in Networks

The mobile learning system has been built, then implemented directly in the mobile network. The location of the measurement is done at five potential points or become the residential areas of the prospective users of the system (students' residences). In the measurement process, we use internet data packets (sim-card flagship data packets) from 2 Internet Service Providers (ISPs), i.e. ISP A and ISP B.

The mobile connection quality measurement tools using 4Gmark [33], is a tool offering a comprehensive and reliable benchmark of the quality of service for smartphones. It allows to test and compare smartphones, networks or places on every technologies 2G (Edge, GPRS), 3G (UMTS, HSDPA, H+, Dual-carrier), 4G (LTE) and WIFI. Both applications support iPhone, iPad, Android devices and Windows Phone [33].

Based on the results presented in Tables 2 and 3, it is explained that for the parameter values of network service quality metrics, they are related to the existing benchmarks, except on the network availability level metric that must be with a benchmark >98%. This has not reached the standard presented in Table 1; it is still below average, and only 79,9% - 85% (2/12), or the internet connection failure rate is 1-3 times out of 12 attempts for internet connection.

The average Internet connection speeds from each ISPs on testing of mobile learning app is presented in Figure 9.

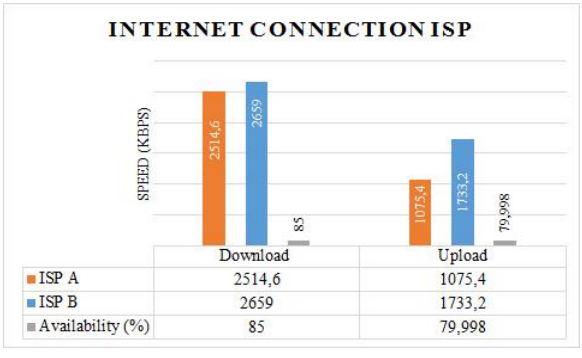

Figure: 9: Average of internet connection speeds on testing of mobile learning

Table. 2
Network Performance QOSE for ISP A

Location	Speed (kbps)		Sensitivity to			
	Down-load	Up-load	Latency (ms)	Jitter (ms)	Packet-loss (%)	Availability (%)
L1	2958	622	69	23,3	0,13	91,67
L2	2581	1045	70	58,02	1,02	83,33
L3	1490	1035	108	32,11	1,17	75
L4	2960	1628	88	23,82	0,84	83,33
L5	2584	1047	94	18,29	1,33	91,67

Table. 3
Network Performance QOSE for ISP B

Location	Speed (kbps)		Sensitivity to			
	Down-load	Up-load	Latency (ms)	Jitter (ms)	Packet-loss (%)	Availability (%)
L1	3060	866	269	44,03	1,1	83,33
L2	2849	3100	109	15,67	2,4	83,33
L3	1490	743	243	43,22	1,8	75
L4	3052	862	130	12,81	3,1	83,33
L5	2844	3095	119	14	0,9	75

The frequent occurrence of failures in the internet connection in the measurement location is influenced by the geographical condition of the region in East-Kalimantan - the trees and its hilly area. In addition, the current network density of internet access at the measurement site is an area of education which of course where most of the users are.

VI. Results and Discussions

The difficulties of students in learning the Data structures course have encouraged teachers to develop a learning tool that utilises a smartphone device owned by students to become a media for teaching. It is a mobile learning media that can be used as a means of presenting lecture materials outside the classroom that can be used anytime and anywhere.

The implementation of the online mobile learning requires resources capabilities. The availability of mobile networks from the Internet Service Provider is sufficient, and for that, we do the measurement and testing of existing network performances.

Based on the results of measurements at 5 points of research locations, the performance rate is in accordance with the standard parameters broadband QoS LIRNEasia. However, for the performance rate of network availability, it is still less than the benchmark value, that is >98% - only 79.9% - 85% (2/12) 1-3 failed attempts out of 12 times of the total internet connection effort made.

The failure of internet connection is caused by the geographical location of the Samarinda city which is at the altitude of 7-25 m, as well as the problem of network traffic density. The number of trees around the location also affect the failure of connecting to the Internet.

VII. Conclusion

From the teaching work in these years, we genuinely feel that the data structures course is so important for students in the study of computer science and technology. How to turn this course from a tedious and challenging course into an exciting course becomes an urgent issue.

The Student teaching experience from previous years into an evaluation that this year is much better. This paper has discussed how the implementation of a mobile learning system with the focus on the media contents. Various methods and technical approaches also are used in its development, including measuring and testing network availability.

Based on the measurement experience and implementation of mobile learning application then:

i. Planning and development of mobile learning should pay attention to factors:
   a) Usability, ease for access applications in networks, ease of use applications, and ease of the understanding of teaching materials. These three things significantly affect the success of mobile learning.
   b) Efficiency, the amount of data used to access app and packaging of materials teaching that attractive and interactive.
ii. The failure of mobile learning applications during testing is generally due to the problem of network availability. The development of mobile learning app must be adapted to the capabilities of existing network performance.

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References

[1] D. Dicheva, A. Hodge, C. Dichev, and K. Irwin, "On the design of an educational game for a Data Structures course," *2016 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE)*, Bangkok, 2016, pp. 14-17. doi: 10.1109/TALE.2016.7851763.

[2] L. Alzubaidi, A. El Hassan, "Data Structures Learning-A Visually Assisted Approach", In Proceedings of *the International Conference on Computer Graphics and Virtual Reality (CGVR)* Jan, 2013, p. 37.

[3] J. A. Crowe, T. Silva, and R. Ceresola, "The Effect of Peer Review on Student Learning Outcomes in a Research Methods Course", *Teaching Sociology*, vol. 43. No. 3, 2015, pp. 201-213.

[4] S. Patel, A literature review on tools for learning data structures, University of Cape Town, 2014.

[5] T. Chen, and T. Sobh, "A tool for data structure visualization and user-defined algorithm animation", In Fr*ontiers in Education Conference, 2001. 31st Annual IEEE*, vol. 1, pp. TID-2, 2001.

[6] P. D. Reddy, S. Iyer and M. Sasikumar, "Teaching and Learning of Divergent and Convergent Thinking through Open-Problem Solving in a Data Structures Course," *2016 International Conference on Learning and Teaching in Computing and Engineering (LaTICE)*, Mumbai, 2016, pp. 178-185. doi: 10.1109/LaTiCE.2016.13.

[7] K. Yu, "Application of a CDIO-based practical teaching system in an architecture major," *World Transactions on Engineering and Technology Education (WIETE)*, Vol.12, No.3, 2014, pp. 568-571.

[8] J. Bai, L. Hu, Y. Li, Z. Tian, L. Xie, L. Wang, M. Zhou, J. Guan, and H. Xie, The progress of CDIO engineering education reform in several China universities: a review. *Procedia - Social and Behavioral Sciences*, vol. 93, 2013, pp. 381-385.

[9] E. B. Costa, A. M Toda, M. A. Mesquita, F. T. Matsunaga, and J. D. Brancher, "Interactive data structure learning platform. In *International Conference on Computational Science and Its Applications*, Springer International Publishing, June 2014, pp. 186-196.

[10] ATSI, Summary Report: Building a Digital Indonesia a Snapshot of the Indonesian Telecommunication Industry 2015, ATSI, Jakarta, 2016.

[11] E. Budiman and O. Wicaksono, "Measuring quality of service for mobile internet services," *2016 2nd International Conference on Science in Information Technology (ICSITech)*, Balikpapan, 2016, pp. 300-305.

[12] W. H. Wu, Y. C. J. Wu, C. Y. Chen, H. Y. Kao, C. H. Lin, and S. H. Huang, "Review of trends from mobile learning studies: A meta-analysis," *Computers & Education*, vol. 59, no. 2, 2012, pp. 817-827.
[13] APJII. (2016). Infografis Survey Penetrasi & Perilaku Pengguna Internet Indonesia 2016. Available at: https://apjii.or.id/survei.
[14] D. Frohberg, C. Göth, and G. Schwabe, "Mobile learning projects–a critical analysis of the state of the art", *Journal of computer assisted learning*, vol. 25, no. 4, 2009, pp. 307-331.
[15] A. S. Drigas, M. A. Pappas, A review of mobile learning applications for mathematics, Learning 3, 2015, p. 6.
[16] P. Marius and S. Anggoro, Profil Pengguna Internet Indonesia 2014, APJII, Jakarta, 2015.
[17] N. Pinkwart, et al. "Educational scenarios for cooperative use of Personal Digital Assistants," *Journal of Computer Assisted Learning*, vol. 19(3), 2003, pp. 383–391.
[18] L. Chen, C. H. Deng, and Y. Yuan. "Study on the application of smartphone technology in college education." Education Management and Management Science: Proceedings of the *International Conference on Education Management and Management Science (ICEMMS 2014)*, August 7-8, 2014, Tianjin, China. Vol. 7. CRC Press, 2015, pp. 191-194.
[19] E. Baran, "A review of research on mobile learning in teacher education," *Educational Technology & Society*, vol. 17. no. 4, 2014, pp. 17-32.
[20] W. Chang, and Q. Tan, "Augmented reality system design and scenario study for location-based adaptive mobile learning," In *Computational Science and Engineering (CSE), 2010 IEEE 13th International Conference on*, Dec, 2010, pp. 20-27.
[21] Q. Tan, X. Zhang, and R. M. Kinshuk, "The 5R adaptation framework for location-based mobile learning systems. In *10th World Conference on Mobile and Contextual Learning*, 2011, pp. 18-21.
[22] ACM and IEEE, Computer Science Curricula 2013: Curriculum Guidelines for Undergraduate Degree Programs in Computer Science, The Joint Task Force on Computing Curricula, Association for Computing Machinery (ACM), IEEE Computer Society, Dec, 2013.
[23] ACM and IEEE, Computer Engineering Curricula 2016: CE2016 Curriculum Guidelines for Undergraduate Degree Programs in Computer Engineering: A Report in the Computing Curricula Series, Joint Task Force on Computer Engineering Curricula Association for Computing Machinery (ACM) - IEEE Computer Society, Dec, 2016.
[24] V. Dyankova, S. Kapralov, M. Yankov, and Y. Ismailov, "A Web-based Educational System for Learning Data Structures", *International Journal of Technical Research and Applications*, vol. 2(5), 2014, pp. 126-132.
[25] Informatics, "Book of Informatics Engineering Program Curriculum Year 2014, Major of ICT University Mulawarman, 2014.
[26] A. Dennis, B. H. Wixom, D. Tegarden, "Systems analysis and design: An object-oriented approach with UML," John Wiley & Sons, Mar, 2015.
[27] LIRNEasia, Broadband Quality of Service Experience (QoSE) Indicators, Annually in March 2014. URL: http://lirneasia.net/
[28] LIRNEasia, Methodology: Fixed Broadband Quality Of Service (QoS) Testing, Annually in March 2014. URL: http://lirneasia.net/
[29] T. J. Research, Standar Kualitas Layanan Data Pada Jaringan Bergerak Seluler (Mobile Data), BadanLitbang SDM, KEMKOMINFO, 2016.
[30] S. Kemp, 2017 Digital Yearbook: Internet, Social Media, And Mobile Data For 239 Countries Around The World, Report: Hootsuite and We Are Social, 2017.
[31] ATSI, Summary Report: Building a Digital Indonesia a Snapshot of the Indonesian Telecommunication Industry 2015, ATSI, Jakarta, 2016
[32] P. Marius and S. Anggoro, Profil Pengguna Internet Indonesia 2014, APJII, Jakarta, 2015.
[33] Qosi, URL: http://www.4gmark.com/the-software.