Journal of Advanced Research in Applied Sciences and Engineering Technology

Journal homepage:
https://semarakilmu.com.my/journals/index.php/applied_sciences_eng_tech/index
ISSN: 2462-1943

A Review on Software Quality Models for Learning Management Systems

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ARTICLE INFO

Article history:
Received 25 May 2023
Received in revised form 13 August 2023
Accepted 20 August 2023
Available online 12 September 2023

Keywords:
Software Quality Model; ISO 9126; Boehm; Learning Management System; usability

ABSTRACT

The objective of this paper is to review the basic software quality model and identify which existing software quality model and quality characteristics are suitable for Learning Management Systems. A literature review was conducted from the following sources - Science Direct, Scopus, and Elsevier. The search terms used are "online learning", "basic software quality model" AND "learning management system". The results of the literature review have identified five main software quality models commonly referred to in software quality literature – McCall, Boehm, FURPS, Dromey, and ISO 9126. In addition, ten common quality attributes for learning management systems identified are maintainability, portability, reliability, efficiency, usability, functionality, security, traceability, availability, and customizability. By identifying the most appropriate software quality model and characteristics for Learning Management Systems, this paper aims to provide guidance to developers and practitioners in the field of online learning to improve the quality and effectiveness of their systems.

1. Introduction

Due to the Movement Control Order (MCO) announcement in Malaysia, most of the sectors had been closed including educational institutions such as universities, schools, and polytechnics. Currently, there are 20 public universities and 41 private universities which have a total enrolment of more than 1.2 million students, in Malaysia [1]. According to previous studies, by 2023, over two-thirds of the world's population will have internet access [2,3]. By 2023, there will be 5.3 billion internet users worldwide, accounting for 66 percent of the global population, up from 3.9 billion in 2018. This may cause all the institutions to continue their method of teaching as online teaching through Learning the Management System (LMS) in the future.

All the institutions had changed their method of teaching and learning from classroom learning to online learning which is known as e-learning. E-learning is a learning system that is conducted based on solemn teaching with the support of electronic resources [4]. Apart from teaching, most of the sector has changed to work from home method.

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https://doi.org/10.37934/araset.32.2.203221

Most of the sector had started depending on software or system in their daily life, such as web systems or mobile applications in continuing teaching, studying, or working. Besides that, there are various new web system that is being launched daily. Even though there are some of the web systems have similar contents, the quality degree may differ as the style of the development differs too [5]. The guidance of the software quality model is important to make sure the application or system works well. According to Azilayati [6], an application has two main or important categories which are internal development and commercial. Moreover, it is important to fulfill the mentioned two main categories to ensure the satisfaction of the users [4]. Besides that, in order to satisfy the user's acceptance, systems need to be delivered as a quality product [7].

In the industry of software development, software developers and engineers are principally concerned about the software design which meets the cost, delivery, and requirements of quality, a characteristic that is mentioned as software quality (SQ) [8]. It is very important for the quality of the systems to be maintained as it is very hard to get a user who had a bad experience using a system with bad quality [5]. According to Boukouchi *et al.,* [9], the success rate of a software product or system is substantially depending on the software quality, which is considered as the crucial design element by the developers, project managers and clients.

There were five basic software quality models introduced for software products [5]. The software quality models are McCall's, Boehm, FURPS, Dromey, and ISO 9126. This paper is intended to contribute to the research about review on software quality models for LMS. The following sections discuss the definition of online learning, definition, and purpose of LMS, software quality definition, the purpose of the software quality model, basic software quality models, discussion about suitable software quality models for LMS and usability criteria in LMS.

2. Related Works

2.1 Learning Management System (LMS)

Learning Management System (LMS) is a web-based application that has multiple functions such as providing notes, conducting classes through video conference, submitting assignments or tasks, and recording the grades or progress of the students [10,49]. According to Al-Sharhan *et al.,* [11], an LMS is a digital gateway that allows teachers and students to effortlessly share classroom information, tools, and tasks. LMSs provide a number of applications and capabilities that enable faculty members to use them for the practices of teaching and learning, as well as to help them monitor students' actions in a more sustainable manner, enabling cooperation, participation, and communication [12,13].

There are several definitions that had been given for online learning. In 1995, when the first web-based LMS was built, the phrase "online learning" was coined [14]. Afterward, the terms emerged and now there are forty-six (46) different terms or overlapping words such as blended learning, e-learning, online courses, distance learning, and online education [14]. Learning content is treated as data, and the course website is treated as a system architecture. Learning content refers to accessible and accurate learning material delivered to students in a timely manner as up-to-date content in our new model, as defined in the current work [15].

Besides that, online learning is thought to be a useful way not only for learning in traditional classrooms but also to establish the concept of lifelong learning [16]. There are various terms being used as a substitute or synonym of online learning. Moreover, online learning is a word that was used to define the learning being conducted through LMS. In another hand, an LMS is a web-based software that makes it easier to provide online, face-to-face, and blended courses, whether in the

classroom or the workplace [17]. In other words, it is a platform that aids in the transmission of educational content through the Internet.

The teaching machine was the first step towards LMS, which was introduced in 1924 [18]. There are various LMS have been introduced after the year 1994. The current LMS, which is commonly used by students are Microsoft Teams, Google Classroom, and WebEx. Sidney Pressey designed the teaching machine, which was a typewriter that could also be used for multiple-choice tests [18]. LMS has proven indispensable in a variety of educational and training environments. LMS is being used by public and private educational institutions to not only develop learner-centered instruction but also to enhance global inclusiveness and increase revenue [19,20].

2.2 Definition of Software Quality

Software quality is an important characteristic that has the steps that are used as the source in providing a product or service to the users that meets their prerequisite and anticipation. There are several definitions that had been given for software quality. In 1988, Deming published a paper in which the author described that the satisfaction of the customer defines the quality of a product or software such as meeting the customer's requirement or perspective [21].

Ishikawa [22] and Feigenbaum [47] further argued that the determination of the quality is done by the client which needs to satisfy the authentic and expected requirements together. The author elaborated on quality control in manufacturing products with quality that can fulfil the consumers' needs. Moreover, the term quality "is important and broadly it should be interpreted as – the quality of product, services, information, processes, people, system, etc". The major fallacy is the notion that quality equates to goodness, richness, or shine [46]. It differs for various reasons for each and every individual [46,48].

Besides that, according to Saini *et al.,* [23], software quality can be described in a variety of ways, including stakeholder satisfaction. It's also known as the Q unit, which stands for the level of stakeholder satisfaction. A developer, a developing corporation, a user, or a client that is using this software are all examples of stakeholders [23]. It indicates that software is of high quality if it meets the needs of end users and is lucrative for the developing company [23,24].

In conclusion, there are various definition given for software quality. However, all the definitions have the mutual concept for software quality which explains that software quality is a procedure to build a product, software, and system which could fulfil the users' requirements and expectations as well.

2.3 Software Quality's Purpose

A model is an abstract representation of reality that allows for the reduction of details and the viewing of an entity or concept from a different perspective [25]. A software quality model is very important in developing software or product as it would act as the guideline of what characteristics need to be included while developing software. According to Djouab and Bari [26], software quality model is used to determine and evaluate the quality specification of software. There is a set of characteristics and sub-characteristics which gives the basis to specify quality needs and evaluation of the quality of an element or system [2].

It is not easy to develop a system or software that satisfies the user. As a guideline, there are various types of software quality models available. However, the software quality model will be chosen based on the requirement needed in developing the system. Besides that, when users are happy with how a system works, it is said to be of high quality. This means that if the system fulfils

the goal for which it was intended and constructed in the first place, and users are happy with it, it is of high quality. Depending on their needs, users have varying perspectives on system usability [27].

3. Methodology

This topic highlighted the research questions and methods used for data collection to identify which software quality model is suitable for LMS.

3.1 Research Question

The main research objective of this study is to investigate the software quality models, quality attributes, and identify suitable existing software quality models for LMS. The research objective has been achieved by answering below research questions:

i. What are the existing software quality models?
ii. What is the suitable software quality model for LMS?
iii. What are the common quality attributes that are being used in software quality models for LMS?

3.2 Search Strategy

The collection of data and analysis were guided by the above research questions. Besides that, to achieve the purpose of this paper, a literature review was utilised to analyse the issues by locating, evaluating, and integrating the data. A methodical, explicit, and repeatable procedure for identifying, evaluating, and synthesising the most recent corpus of completed and documented studies by researchers, scholars, and professionals is referred to as a systematic literature review [51,52,53]. There are various keywords and search engines used to collect articles that would help in answering the research questions.

The databases that have been used for scholarly articles include Elsevier, Scopus, Google Scholar, and Science Direct [52]. Among these, Scopus and Google Scholar are the most used to search and retrieve indexed publications. An advanced searching method had been performed through Google Scholar by using the following search string: TS ((“online learning”) and (“software quality” OR “software quality model” OR basic software quality model”) and (“learning management system”)). The search string retrieved various articles that were published between 2016-2022, demanding a combination of words in titles, keywords, or abstracts.

The search has returned 600 results including research articles, proceeding papers, book chapters, review articles, editorial materials, and early articles. However, the current study only contemplated conference proceedings, review articles, and research articles which reduces the number of results to 250. Besides that, there a few selection criteria are included in selecting the relevant articles for the study. The selection criteria are as follows:

i. Search field: “online learning”, “software quality model” and “learning management system”
ii. Limit to: Full Text and Peer Review
iii. Document Type: Journal Article
iv. Language: English
v. Sources: Scopus, Elsevier, Science Direct

The total number of articles used for this study is 53 after including relevant and excluding irrelevant papers. The detailed breakdown of the searched articles is shown in the flowchart below as Figure 1.

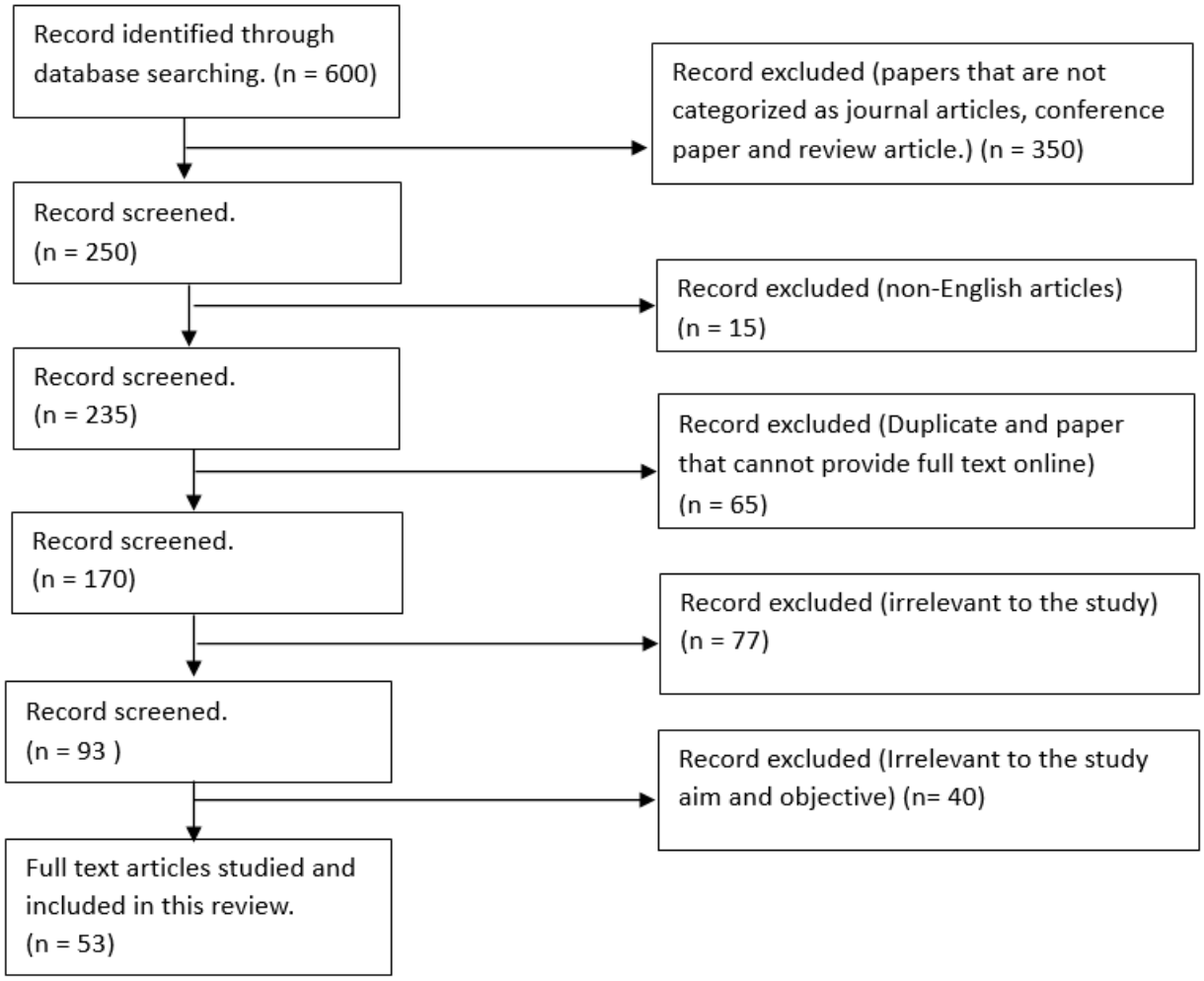

Fig. 1. Flowchart of paper studied [51]

4. Results

There are two categories of software quality models which are basic and tailored. The literature review highlighted five main or basic software quality models commonly used. Software quality models which were developed until 2000 are categorized as basic software quality models and software quality models that was developed after the year 2000 are known as tailored [5]. The proposed basic software quality models are McCall's, Boehm, FURPS, DROMEY, and ISO 9126 [25,28]. Meanwhile, the proposed tailored software quality models are Bertoa Model, GEQUAMO, Alvaro Model, Rawashdeh Model, QualOSS Model, and SQO-OSS Model. The tailored or non-basic models are giving more importance or focus on the use of Commercial Off-The Shelf Components (COTS) [5]. This section discusses the basic software quality models.

4.1 McCall's Software Quality Model

The first quality model is proposed or presented by Jim McCall, in relation to the system development process and system developers [26,29]. According to Buenaflor [30], Jim McCall has presented this software quality model for the US Air Force The purpose of this quality model proposed was to connect the gap between the developers and users. McCall tried to map the view of the user with the priority of the developer. There are three main perspectives are used in characterizing the quality attributes of a software or system. The perspectives are:

i. Product revision
ii. Product transition
iii. Product operations

Each perspective identifies its own quality attributes. The first perspective is product transition. This perspective identifies the quality attributes which influence the ability to modify the software product. The second perspective is product transition which identifies the quality attributes that influences the ability to adapt the software in new environments. The third perspective is product operation which identifies the quality attribute that influences the extent to which the software satisfies or fulfils its requirements. The attributes identified in each perspective is shown in Table 1 below. Besides that, Figure 2 shows the diagram of McCall's software quality model.

Table 1
Perspectives and attributes of McCall's quality model

Perspectives	Quality Attributes	Function
Product revision	Maintainability	Ability to identify and fix the defect.
	Flexibility	Ability to make required changes as influenced by the business.
	Testability	Ability to validate the software requirements.
Product Transition	Portability	Ability to transmit the software from one environment to another environment.
	Reusability	Ease in utilizing existing software elements in a various framework.
	Interoperability	The degree or ease where the software elements or components can work together.
Product Operations	Correctness	The functionality which matches the requirement.
	Reliability	The degree where the system crashes.
	Efficiency	The usage of system resource which includes the CPU, disk, network, and memory.
	Integrity	Protection from the access of unauthorized.
	Usability	Ease of use

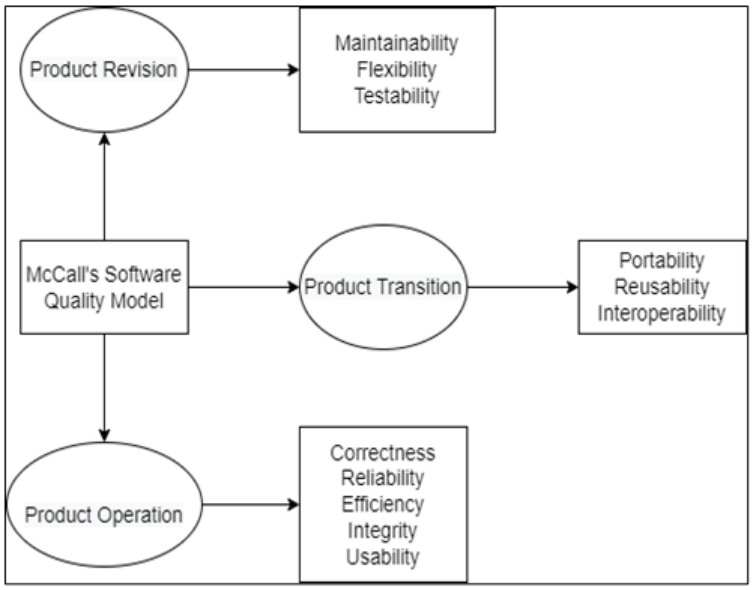

Fig. 2. Perspectives and attributes of McCall's quality model (adapted from Ramulu *et al.,* [31])

In conclusion, there are total of 11 quality attributes identified which is broken down by the three perspectives. McCall has defined one or more quality criteria for each quality attributes.

4.2 Boehm's Software Quality Model

The second basic software quality model was proposed by Barry W. Boehm in 1978 [29]. The software quality model is known as Boehm software quality model. This model is introduced to evaluate the software quality automatically and quantitatively. Besides that, Boehm's model was introduced to overcome the issues of McCall's model. Figure 3 shows the diagram of Boehm's software quality model.

Hardware performance is included in Boehm's quality model as it is missing McCall's model [32]. Boehm's software quality model consists of three hierarchy level which are high level as primary characteristics, intermediate level, and lower level as primitive characteristics. The model mainly represents seven quality characteristics which are portability, usability, maintainability, human engineering, understandability, flexibility, and testability. The flaws of models that automatically and objectively evaluate software quality are also discussed in Boehm's model [32].

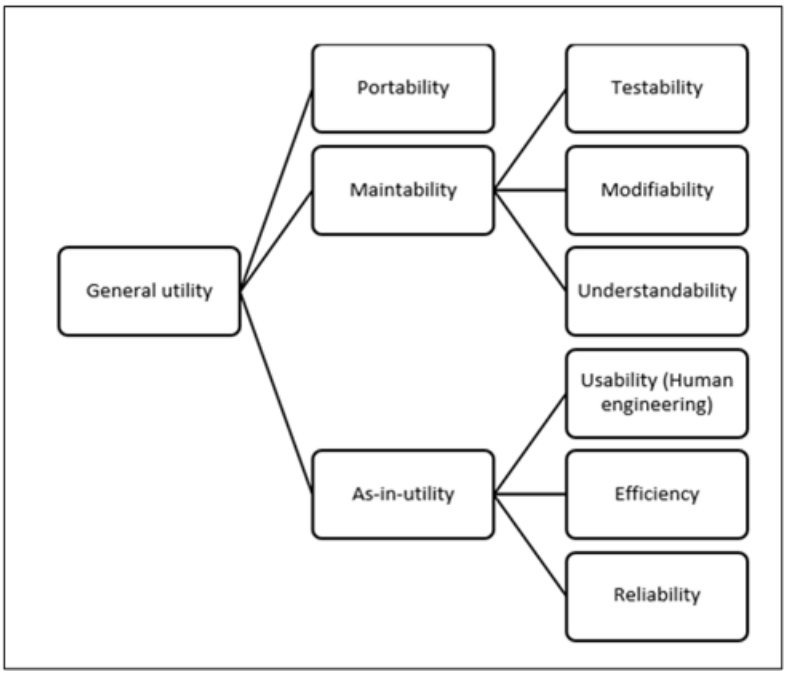

Fig. 3. Quality attributes of Boehm's quality model (adapted from Ramulu *et al.,* [31])

4.3 FURPS Software Quality Model

The third basic software quality model was proposed by Robert Grady in 1992 [29]. The software quality model is known as FURPS software quality model. Later the model was extended by Rational Software. The FURPS software quality model focuses on five main quality characteristics or attributes which are functionality, usability, reliability, performance, and supportability. The model is named FURPS from the initial of each quality characteristic. The attributes identified and the explanation for each attribute are provided in Table 2. Besides that, Figure 4 shows the diagram of FURPS's software quality model.

Table 2
Quality attributes of FURPS software quality model

Quality characteristics	Explanation
Functionality	Includes the capabilities, security, and features sets.
Usability	Includes the user interface consistency, training materials, documentation of user and human factors.
Reliability	Includes the recoverability, frequency and seriousness of malfunction, accuracy, and the mean time between failures.
Performance	Enforces on functional requirement such as efficiency, accuracy, speed, recovery time, resource usage and response time.
Supportability	Includes adaptability, serviceability, compatibility, and testability.

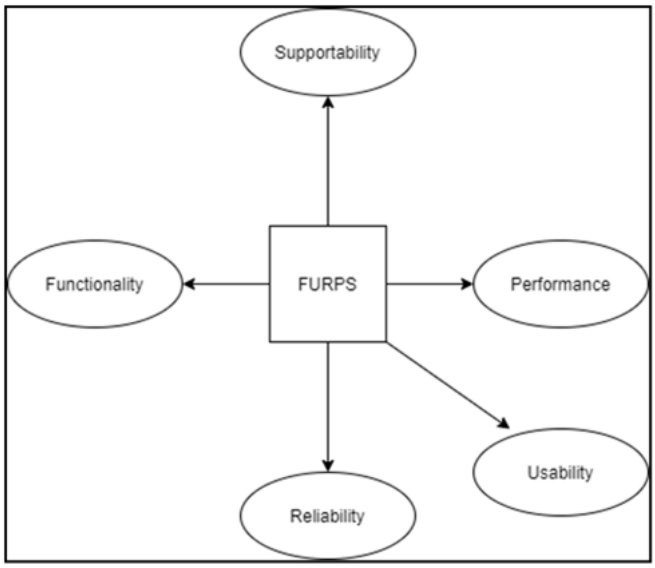

Fig. 4. Quality attributes of FURPS quality model (adapted from Ramulu *et al.,* [31])

4.4 Dromey Software Quality Model

The fourth software quality model was proposed by R. Geoff Dromey in 1995 [29]. The software quality model is known as Dromey. The quality model is focused on the relationship between the quality characteristics and sub-quality characteristics to link the software product properties with the software quality attributes. The Dromey's quality model has four categories that consist of quality attributes. The categories are correctness, internal, contextual, and descriptive. However, there is a disadvantage which is related to maintainability and reliability as it is not possible to judge before the software product starts functioning in the production area. Figure 5 shows the diagram of Dromey's software quality model.

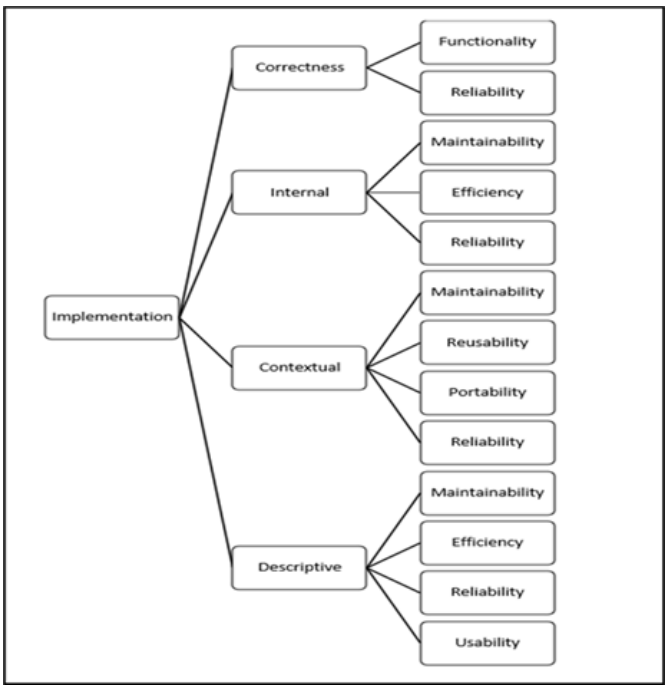

Fig. 5. Quality attributed of DROMEY quality model (adapted from Ramulu *et al.,* [31])

4.5 ISO 9126 Software Quality Model

ISO 9126 is an international standard that is used for the evaluation of software. ISO 9126 represents the latest or newest study describing software for the purpose of software quality assurance, software quality control, and software improvement process (SPI) [31]. Table 3 below shows the ISO/IEC 9126 Category and an explanation for each category. The standard of ISO 9126 is divided into four parts. The four parts are:

i. Quality model
ii. External metrics
iii. Internal metrics
iv. Quality in use metrics

Table 3
Four parts of ISO 9126 standard

ISO/IEC 9126 Category	Explanation
ISO/IEC 9126 – 1 (Quality model)	Provides the preferred quality model for the finished version, which includes the main quality attributes.
ISO/IEC 9126 – 2 (External metrics)	External quality metrics are provided to assess the software quality characteristics that are appropriate for an operable software application or product during development training and testing samples and after it enters the operational processes.
ISO/IEC 9126 – 3 (Internal metrics)	Provides the quality of internal metrics for measuring software quality characteristics that can be used to a non-executable software quality product during the design and implementation phase of the development.
ISO/IEC 9126 – 4 (Quality in use metrics)	Deliver quality-in-use metrics for assessing the software quality attributes of an operational software product once it enters the operation process.

ISO 9126 is the extension of the previous quality model, which is done by McCall in 1977, Boehm in 1978, FURPS, and others. There are six main quality characteristics and 21 sub-characteristics identified in ISO 9126 [31,33,34]. The characteristics are broken down into a few sub-characteristics. Figure 6 shows the characteristics and sub-characteristics of ISO 9126 quality model. Meanwhile, Table 4 shows the definition of each characteristic and sub characteristics.

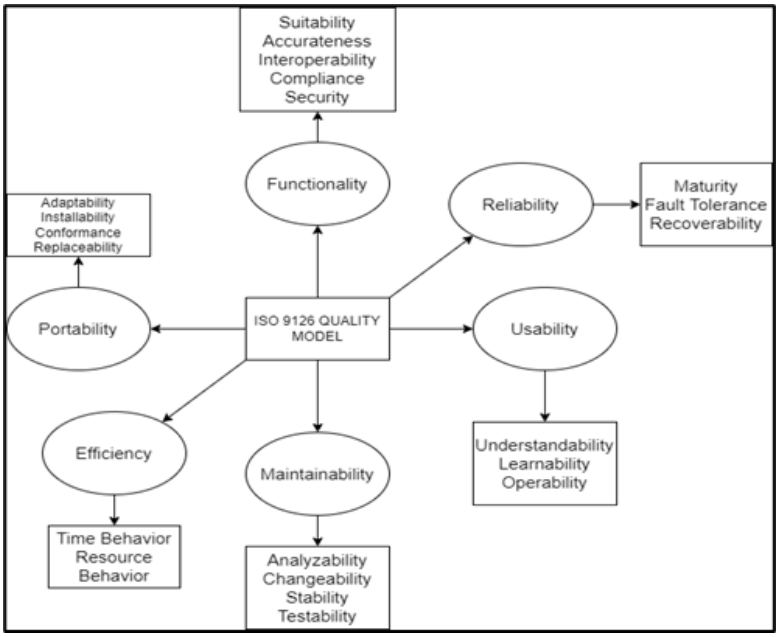

Fig. 6. Characteristics and sub-characteristics of ISO 9126 quality model (adapted from Ramulu *et al.,* [31])

Table 4
Definition of characteristics and sub-characteristics of ISO 9126 quality model (adapted from Dzulfiqar *et al.,* [34])

Characteristics	Characteristics Definition	Sub-Characteristics	Sub Characteristics Definition
Functionality	Relates to the existence of a group of functions and required properties.	Suitability	Relates to the presence and appropriateness of the group of functions for stated tasks.
		Accurateness	Relates to the correctness of the functions.
		Interoperability	Refers to a software element's capacity to communicate with another element.
		Compliance	Addresses to the compliant ability of the software.
		Security	Refers to access of unauthorized to the software functions.
Reliability	Relates to the capability of the software to maintain performance level under specified conditions for specified time.	Maturity	Concerns on the occurrence of failure by the faults in the software.
		Fault Tolerance	Ability of the software in recovering or resist from the environmental or component failure.
		Recoverability	Ability in bringing back the failed system to the full operation including the network connection and information.
Usability	Relates to the ease of use for a specified function.	Understandability	Refer to the effort of user in understanding the logical function of a software.
		Learnability	Refer to the learning effort for each user.
		Operability	Ability in operating the software by a user in the given environment.

Maintainability	Refer to the ability in identifying the error within a software component.	Analyzability	Ability in identifying the core cause of a malfunction in the software.
		Changeability	Refer to the effort needed in changing a system.
		Stability	Refer to the risk of unpredicted effect due to alterations or modifications in a system.
		Testability	Refer to the effort required in validating the software that is modified.
Efficiency	Concerned on the resource of system used when delivering the needed functionality.	Time Behaviour	Relates to response time and processing time.
		Resource Behaviour	Relates to the number of resources used.
Portability	Relates to ability of how well the software can be transferred from one environment to another.	Adaptability	The ability in changing to new requirement for operating environments.
		Install ability	Relates to the effort required in installing the software.
		Conformance	Like the functionality compliance but the characteristics refer to the portability.
		Replaceability	Refer to the how easy it is in exchanging a provided software component into a specified environment.

In conclusion, ISO 9126 software has identified six main characteristics and twenty-one sub-characteristics. Even though the overall structure is almost like the past models, there is a number of noticeable differences.

5. Discussion

5.1 Software Quality Model for Learning Management System (LMS)

This topic highlighted the quality characteristics for LMS and identified which existing software quality model is suitable for LMS. Three papers, P1, P2, and P3 are selected as the reference to identify the suitable software quality model for LMS [7,18,35]. The papers are selected based on the content which discussed about the software quality model, quality attributes, LMS, and web application. Besides that, these papers are selected as the reference as it discusses the quality model and quality attribute that would be suitable in developing an LMS that has good quality.

Table 5 shows the comparison of proposed quality characteristics for LMS. P1, P2, and P3 were used as the reference to identify which characteristics are being used commonly [7,18,35]. Each study presented its own software quality model, with the authors relying on the ISO 9126 quality model as a baseline.

Table 5
Comparison of quality characteristic for LMS using ISO 9126

Software Quality Model / Quality Attributes	P1 [18]	P2 [7]	P3 [35]
Maintainability	✓	✓	✓
Flexibility			
Portability	✓	✓	✓
Reusability		✓	
Interoperability		✓	✓
Correctness			
Reliability	✓	✓	✓
Efficiency	✓	✓	✓
Integrity			
Usability/Human Engineering	✓	✓	✓
Testability		✓	
Modifiability			
Understandability		✓	✓
Functionality	✓	✓	✓
Performance			
Supportability			
Learnability			✓
Attractiveness			✓
Security		✓	
Traceability		✓	
Availability		✓	
Customizability		✓	
Total	6	14	10

Most of the web applications used ISO 9126 as the base [7]. ISO 9126 is a framework that is provided for software development. In general, the standard model is described in ISO/IEC 9126-1, external metrics are described in 9126-2, internal metrics are explained in 9126-3, and quality in use metrics are summarized in ISO/IEC 9126-4. The international standard ISO/IEC 9126-1 is the international standard, while 9126-2, 9126-3, and 9126-4 are technical reports [35].

From the discussion in this section, it can be concluded that ISO 9126 is the suitable software quality model for LMS. The authors of three papers have used ISO 9126 software quality model as the base to propose a quality model for LMS. Moreover, the quality characteristics are well explained and easy to understand which can be used to develop a system. Besides that, the characteristics is broken into sub-characteristics and explained in detail for each of them.

5.2 Quality Attributes for Learning Management System (LMS)

E-learning is defined as "a learning method that uses information and communication technologies (ICTs) to enhance the teaching and learning process and facilitate the acquisition and application of knowledge [36]." In higher education, an academic application is crucial since it allowed users to manage their everyday activities through the system [7]. Colleges and universities can use LMSs to gather, save, and process data for business information, qualitative, and prescriptive modelling [37]. There are two major contexts that may be abstracted to evaluate educational software: the teaching sector and the computer field [18]. Plaza *et al.,* [18], stated ISO/IEC 9126 family describes the two-part model for the quality of software.

There are several quality characteristics identified through the software quality models. However, Suradi *et al.,* [7] have narrowed down the suitable quality characteristics for the web application

which includes e-commerce, educational applications, and e-government (refer to Table 6). Even though the quality characteristics for web applications are made, three refinements have been made to come out with the finalized software quality characteristics for an academic application. Once the identification of quality attributes is completed, a list of academic application characteristics is identified and listed (refer to Table 7).

Table 6 shows the comparison of quality characteristics among the basic quality models which are [a] McCall's, [b] Boehm, [c] FURPS, [d] Dromey, and [e] ISO 9126. Apart from that, all the basic software quality model has proposed quality characteristics only. However, only [e] ISO 9126 has proposed quality characteristics and sub-quality characteristics. The table recorded the combined quality characteristics and sub-quality characteristics for [e] and quality characteristics for other [a], [b], [c], and [d].

Table 6
Web application quality factors ranking [4]

Quality factor	Rank
Efficiency	1
Security	2
Usability	3
Traceability	4
Availability	5
Scalability	6
Functionality	7
Customizability	8
Recoverability	9
Consistency (Data)	10

Table 7
List of characteristics for academic application (adapted from Suradi *et al.,* [7])

No	Quality Factor Characteristics	Origin Model All basic model
1	Reliability	
2	Efficiency	
3	Usability	
4	Maintainability	
5	Testability/Maintainability	
6	Portability	
7	Reusability	
8	Interoperability/Functionality	
9	Understandability/Usability	
10	Security	Web Application Quality
11	Traceability	
12	Availability	
13	Customizability	

The quality attributes being used in each quality model have been recorded through the comparison in Table 8. The total frequency of each quality attribute used is shown in Table 9. There are seven quality attributes that is used commonly in all the basic software quality models. It is decided as most used if the frequency of usage is more than 2 as there are five models. The frequently used quality attributes are maintainability, portability, reliability, efficiency, usability or human engineering, testability, and functionality.

Table 8
Comparison of quality characteristic among basic software quality models

Software Quality Model / Quality Attributes	[a] [26,30,38]	[b] [30,31,38]	[c] [31,32,38]	[d] [31,32,38]	[e] [7,31,35,38]
Maintainability	✓			✓	✓
Flexibility	✓				
Portability	✓	✓		✓	✓
Reusability	✓			✓	
Interoperability	✓				✓
Correctness	✓				
Reliability	✓	✓	✓	✓	✓
Efficiency	✓	✓		✓	✓
Integrity	✓				
Usability / Human Engineering	✓	✓	✓	✓	✓
Testability	✓	✓			✓
Modifiability		✓			
Understandability		✓			✓
Functionality			✓	✓	✓
Performance			✓		
Supportability			✓		
Learnability					✓
Security					✓
Availability					✓
Total	10	7	5	7	12

Table 9
Frequency of quality attributes used among basic software quality models

Software Quality Model / Quality Attributes	Frequency
Maintainability	3
Flexibility	1
Portability	4
Reusability	2
Interoperability	2
Correctness	1
Reliability	5
Efficiency	4
Integrity	1
Usability / Human Engineering	5
Testability	3
Modifiability	1
Understandability	2
Functionality	3
Performance	1
Supportability	1
Learnability	1
Security	1
Availability	1

It can be concluded that the suitable quality characteristics for LMS are maintainability, portability, reliability, efficiency, usability, and functionality. Besides that, four unique quality characteristics which would support the LMS are security, traceability, availability, and customizability. There are six quality characteristics that is commonly used in all three papers P1, P2, and P3 (refer to Table 5) [7,18,35]. The quality characteristics are maintainability, portability, reliability, efficiency, usability, and functionality. Meanwhile, interoperability and understandability are used in Suradi *et al.,* [7] and Smith [35]. However, Suradi *et al.,* [7] have specified four unique characteristics which would be useful to develop an educational system or LMS which are security, traceability, availability, and customizability.

5.3 Usability Metrics in Quality Model for Learning Management System

The concept, definition, and importance of usability metrics were discussed as it is a quality attribute that is commonly used in all the five basic software quality models (Refer to Table 6). The usability concept is developed from user-friendly terms and defined as the comfort of use of the system [39]. A system should be user-friendly and accessible, and it also must be able to offer effective and consistent information [5]. Besides that, a system should be able to provide a better user interface and design which would meet the expectation and requirements of the users.

In software engineering, one of the most crucial software quality attributes or metrics is usability. The ISO/IEC 9126 redefined usability as the ability of software to be understood, used, learned, and liked by the user under specified conditions [39,40,50]. There are five sub-attributes categorized under usability attributes. The sub-attributes are efficiency, errors, learnability, memorability, and satisfaction. However, ISO 9241-11 defines usability as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use" [41,42]. Planning a task that replicates future use of the system, choosing a method or process to utilize for the assessment, and deciding on the sort of data to be collected and how to collect are all part of usability evaluations [43]. Several steps are required for usability evaluation, including task planning to improve future use, selecting the evaluation procedure or methodologies, and determining the kind and source of data to be collected [43].

In general, a LMS has been used by institutions for planning, implementation, facilitating, and monitoring the learning of students [44]. Usability attribute is vital in LMS as it gives a better collaboration of human-computer. A good usability feature could improve the learning backgrounds of the students and also enhances a person's performance in academic. Besides that, an LMS makes the learning experience safer for students, allowing them to participate more actively and providing educators with a customized learning system [45].

6. Conclusions

This study discussed the basic software quality model. The main research objective of this study is to investigate the software quality models and its quality attributes and identify the suitable existing software quality model that can be used for LMS. The first research question is what are the existing software quality models? There are five basic software quality models that is introduced before the year 2000. Non-basic software quality model is introduced using the basic software quality model as the base. The methodology used to collect and analyze data is through collecting relatable articles in various search engines and sources such as Scopus, Elsevier, and Science Direct

Besides that, the result and discussion section discussed suitable software quality models and quality attributes for LMS which would help to achieve the second and third research objectives. The

second research question is what are the suitable software quality models for LMS? A comparison among quality attributes is made to identify which quality model is suitable to develop an LMS. Through the comparison, it is found that P1, P2, and P3 had proposed an enhanced software quality model for LMS using ISO 9126 as the base [7,18,35]. Apart from that according to Suradi *et al.,* [7], most of the web applications use ISO 9126 as the base.

The third research question is about identifying the common quality attributes that are being used for LMS. A comparison between quality attributes from three different papers P1, P2, and P3 is made [7,18,35]. The quality characteristics are maintainability, portability, reliability, efficiency, usability, and functionality. Besides that, four unique characteristics were identified as it would be useful to develop an educational system or LMS which are security, traceability, availability, and customizability.

For future research, researchers may improve the quality metrics. There are several quality models introduced. However, improving the metrics is very important as it would affect the quality of the system or software. As for LMS, usability is very important because it affects the user's experience in using a system. Researchers may improve the usability metrics for a better experience through the quality model.

Acknowledgement
This study is sponsored by the, Fakulti Teknologi Maklumat dan Komunikasi, Universiti Teknikal Malaysia Melaka (UTeM).

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