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Systematic Review on Software Quality in Educational Applications

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ABSTRACT Approaches in teaching and learning have transformed significantly in tandem with the advances in computerised applications to support the process. Software quality characteristics such as usability is one of the non-functional requirements that must be taken into consideration when designing and developing educational applications. This study focuses on two characteristics of quality in use (effectiveness and satisfaction) and three usability sub-characteristics (learnability, user interface aesthetic, and appropriateness recognisability) that can be used to evaluate the quality of such educational applications. It adopted the systematic literature review method to explore existing works that concern the two quality in use characteristics and the three usability sub-characteristics in their studies. The results provide the insight on the related works and their gaps specifically in developing educational applications.

INDEX TERMS Software quality, quality in use, effectiveness, satisfaction, usability characteristic, learnability, user interface aesthetic, appropriateness recognisability, educational applications.

I. INTRODUCTION

The education market has recently switched into a lucrative business niche, especially for software developers who produce educational applications. Various techniques have been applied to satisfy current trends in the educational field. For instance, the development of educational applications applies human-computer interaction (HCI) with an effective collaborative learning environment to help develop and understand an application design [1]. By applying modern and attractive techniques, both teachers and students have more interest to build their knowledge by exploring educational applications [2].

Modern methods of learning represent an efficient methodology in teaching students using educational applications [3]. In addition, educational applications in the 21st century classroom environment should include tasks that require students to work cooperatively [4]. To create the desired 21st century learning environment, various ideas and efforts have been implemented to deliver Information and Communication Technology (ICT) facilities that are needed in schools, including the use of educational applications [5]. Educational applications that have been implemented in today's market can be further improved to motivate the learning process [6]. In motivating teachers' and students' satisfaction, educational applications may consider not only users' needs but should also include multiple criteria such as existing educational guidelines, software quality that relate with non-functional requirements (NFRs) as well as engagement such as time, attention, and emotion [7].

Typically, developers especially novices, do not realise the importance of NFRs during the application development, particularly for complex applications, which have multiple functions. They should be aware and define the NFRs at the early stage to avoid latent problems [8], which involve quality characteristics in any software development, including educational applications. Software quality in an application can be defined from various aspects. For example, an educational application should include learning materials as a functional requirement at the same it should fulfil satisfaction aspect as one of the NFRs. Educators will gain benefits as it can reduce their workloads and efforts [9].

Hence, software developers should clearly understand and be concern about users' needs, which formally align with

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functional requirements and NFRs besides other provided policies or rules in the education domain. Quality characteristics in relation to NFRs need to be considered seriously and the same understanding among the developers especially in quality will contribute to effective and efficient applications that is normally difficult to achieve [10].

This research aims to report the systematic review on two characteristics of quality in use (effectiveness and satisfaction) and three usability sub-characteristics (learnability, user interface aesthetic, and appropriateness recognisability) that can be referred by software developers to reach the same understanding in software development activities. This study refers to ISO/IEC 9126:2001 [11] that was technically revised and replaced with ISO/IEC 25010:2011 [12] to define the concerned software quality. In addition, it focuses on the quality concerning educational applications. Thus, the results from the systematic review highlight the issues and gaps of existing works that focus on the related software quality in developing educational applications and provide the input for guiding software developers when designing such applications. This systematic literature review (SLR) adopts the method as proposed by Kitchenham [13]. A total of fifty papers were selected through a systematic search process that are further elaborated in respective sections. The results fill the gaps of existing systematic and non-systematic reviews on the issues, besides related primary works.

Section 2 describes the related work before moving to Section 3 that elaborates the review process and the analysis that supports the reliability and dependency of the data. Section 4 reports the results from the conducted review, while Section 5 summarises the study. Finally, Section 6 concludes the work and proposes the future work.

II. RELATED WORK

This SLR involves an in-depth review and analysis of recent works from 2015 to the first quarter of 2020. To ensure the amount of research conducted on concerned software quality in the educational application domain, an extensive article search process was carried out. The search focused on SLR works under different publication categories that are conferences (CR), journals (JR), early articles (EA), and magazines (MG) from IEEEXplore Digital Library subscribed by Universiti Teknologi Malaysia. The search results were recorded for further analysis as listed in Table 1.

Fig. 1 shows the results from the search using two different sets of keywords. Only 28 articles (5.43%) matched the first search keywords (''systematic literature review'' AND ''usability'' AND ''application'') as compared to another search keywords (''systematic literature review'' AND ''application''), which consist of 488 articles (94.57%). Therefore, it can be concluded that in six years, there remains a lower amount of SLR works related to software quality in educational applications as compared to SLRs in the application domain published by IEEE. Then, papers published in the period of 2015 to 2020 were selected to check on their discussion about the issues and gaps in terms of the concerned quality characteristics.

TABLE 1. Search on SLR papers based on search keywords.

Search Keyword	(("All Metadata":systematic literature review) AND "All Metadata":usability) AND "All Metadata":application)				("All Metadata":systematic literature review) AND "All Metadata":application			
Category / Year	CF	JR	EA	MG	CF	JR	AR	MG
2020	13	2	0	0	106	51	8	1
2019	1	3	0	0	88	29	4	2
2018	4	0	0	0	62	13	0	0
2017	2	0	0	0	40	19	0	0
2016	0	0	0	0	33	1	1	1
2015	2	0	0	1	20	4	2	3
Total	28				488			

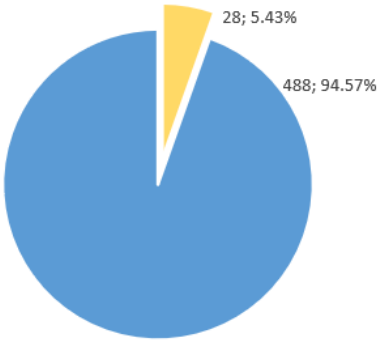

FIGURE 1. Results by search keywords.

A. ISSUES AND GAPS

Existing SLRs that mention the quality characteristics are listed in Table 2 to examine the reported characteristics or sub-characteristics in the works and not limited to what concerned in this study.

The selected 10 articles in Table 2 show that the recent works have applied SLRs in their works, which focus on software quality in the concerned application domain. Hence, the listed characteristics or sub-characteristics show that none of the reviews cover all the concerned two characteristics of quality in use (effectiveness and satisfaction) and three usability sub-characteristics (learnability, user interface aesthetic, and appropriateness recognisability) as in our study. In addition, the results show the limited use of the SLR technique, especially for investigating quality characteristics in educational applications. Inspired from both gaps, this SLR had been conducted with the aim to explore the issues and gaps of the concerned software quality.

B. EXISTING WORKS ON QUALITY CHARACTERISTICS OR SUB-CHARACTERISTICS

This study further investigated the existing issues that focus on usability, effectiveness, satisfaction, learnability, user interface aesthetic and appropriateness recognisability.

1) USABILITY

Nowadays, educational applications are dynamic and continuously improve in term of convenience and usability, where

TABLE 2. Quality characteristics in existing works.

Article	Discussion	Characteristic / Sub-characteristic
[10]	SLR work to search and select articles that provide insights on attractiveness and learnability sub-characteristics that lead to user satisfaction, ease of use and reduce time during completing a given task.	Attractiveness, Learnability
[14]	SLR work that gathers articles and highlight issues in user interface design for Web applications	Satisfaction, Understandability, Attractiveness, Learnability
[15]	A review to gather information on the importance of balance between security and usability of an application	Security, Quality
[16]	A work that analyses and summarises the recent tools and methods for MUI development	Functionality, Usability, Reliability, Performance, Supportability
[17]	Investigates issues, problems and solutions, while adapting a UCD interface on mobile applications	Quality
[18]	SLR on how video game live streaming can affect user participation (streamers and audiences) in daily life that can drive to mental health issues of Internet addiction	Attractiveness, Satisfaction
[19]	SLR that is concerned about the usability model to measure m-GBL; critical findings were explored and gathered.	Usability, Learnability, Efficiency, Memorability, Errors, Satisfaction.
[20]	A review to gather input from selected papers which comply with defined sub-characteristics in educational applications.	Satisfaction, Usability
[21]	SLR to trace usability heuristics and evaluation before weeding can be performed	Visibility, Flexibility, Aesthetic, learnability, Efficiency, Memorability, Satisfaction
[22]	A relevant work to identify heuristics applicable to the evaluation of the usability of educational games.	Usability, Satisfaction, Effectiveness, Efficiency

ease of use of such applications need to be considered in various activities to manage numerous instructive components in the applications [24]. Typically, structuring, creating, and assessing educational applications require users' involvement that should conform to the usability characteristic and fulfil necessary requirements [25]. Furthermore, an existing work that applied a heuristic evaluation reported that usability characteristics may differ for different educational applications based on the research scope [26]. Related works show that usability is a vital key for ease of use, where it helps produce good educational applications.

2) EFFECTIVENESS

A study reports that even though there are reviews on usability and effectiveness, the topics addressed were not related to the domain of technology and educational applications [27]. Patterson *et al.* [28] state that effectiveness is a combination of reliability and validity characteristics. Their cross-sectional study partially discussed the effectiveness characteristic where the focus was only on reliability estimates rather than validity as an indicator of quality. Another work concluded that software developers need guidance to produce an effective application using a framework mainly among novice software engineers [29].

3) SATISFACTION

User satisfaction needs to be improved including ease of the user interface to drive the loyalty in using an application, but some applications lack of NFRs such as satisfaction [30]. Furthermore, HCI provides the guide that individuals should connect with each other to derive user satisfaction, where an application should be designed to meet this sub-characteristic. However, software developers mainly novices are still lack of this awareness [31]. Hence, designing educational applications for inquiry-based learning activities must include the concept of visualisation to motivate user satisfaction and to easily help students in understanding and learning the concepts [32]. Existing works show that the satisfaction sub-characteristic is important in developing educational applications.

4) LEARNABILITY

In the education field, developers need to focus on user needs, whereby learnability and understandability are among major sub-characteristics to indicate that an application is well designed. Both criteria can cause a conflict when developers do not clearly understand how to fulfil them [33]. Learnability does not only depend on exploring activities, but it should also include client desires, where it possibly emphasises insignificant activities at any navigation levels of an educational application [34]. Roldan *et al.* [35] compared the user interface design of authoring tools for teachers and reported that most tools seem to overlook the importance of learnability, such as providing clumsy user interfaces that do not integrate related activities in the applications.

5) USER INTERFACE AESTHETIC

Kolekar *et al.* [36] state that Moodle framework does not provide the dynamic features of a website, despite recent trends suggest that students prefer online education as compared to room coaching in traditional classrooms. Furthermore, Yang *et al.* [37] found that users applied short term memories, depending on the system user interface. However, due to the characteristics of mobile devices, such as small screen size and mobility, developers need a reference to employ and measure user experience.

6) APPROPRIATENESS RECOGNISABILITY

Building new knowledge and skills involves various experiences and challenges for users to meet the appropriateness recognisability sub-characteristic in completing their tasks [38]. Furthermore, the ability to use technological tools, remember and recognise new knowledge, need to involve other new abilities [39]. Most of the information can be delivered in a simple and straightforward manner, but it needs to fulfil the appropriateness recognisability sub-characteristic. The information should represent new skills, which make the interface quick to understand and easy to navigate [40].

Based on the listed issues in the aforementioned sub-sections, our SLR further investigates other solutions, issues and gaps for implementing concerned software quality in educational applications.

III. REVIEW PROCESS

This research adopts the SLR method by Kitchenham [13]. The steps are elaborated in the following sub-sections as portrayed in Fig. 2.

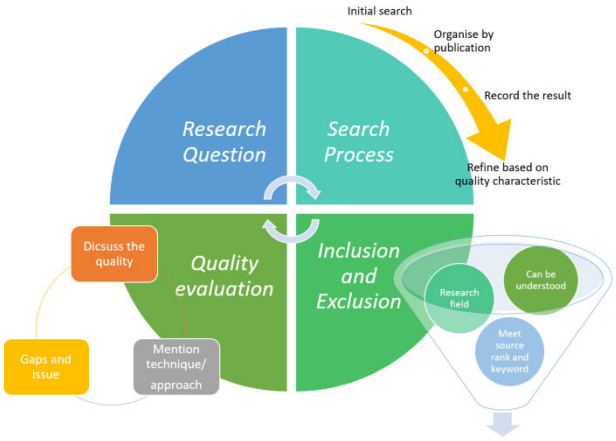

FIGURE 2. The review process for search and inclusion of quality characteristics.

The search process involved four main activities. Firstly, three research questions were formulated. Then, the selection of the articles was performed using search keywords on qualified resources. The initial results had a large volume that was recorded for further activity. The articles were then sorted in a systematic manner where they were organised by publication and year. The third main step is inclusion and exclusion criteria in which only articles that can be understood, discuss related fields, and meet the search keywords should be selected. Only 50 articles were selected at the final stage. Finally, the selected papers were further discussed to answer the research questions.

A. RESEARCH QUESTION

To identify the research questions, several criteria must be taken into consideration which are population, intervention, comparison, and outcomes as shown in Table 3.

Based on the criteria in Table 3, the formulated research questions (RQs) are as follows:

1) *RQ1:* Do the articles clearly discuss user interface aesthetics, learnability, appropriateness recognisability, satisfaction, and effectiveness in educational applications?
2) *RQ2:* Are the techniques or approaches clearly defined in the research?
3) *RQ3:* Do the articles discuss the gaps in the existing works?

TABLE 3. Criteria for research questions.

Criteria	Scope
Population	Papers that propose techniques or approaches to improve user interface aesthetics, learnability, appropriateness recognisability, satisfaction, and effectiveness sub-characteristics in educational applications.
Intervention	Techniques or approaches that address issues of user interface aesthetics, learnability, appropriateness recognisability, satisfaction, and effectiveness.
Comparison	Strengths and weaknesses for each approach
Outcomes	Issues and gaps in user interface aesthetics, learnability, appropriateness recognisability, satisfaction and effectiveness sub-characteristics in educational applications, and the proposed techniques or approaches to overcome the mentioned issues.

B. SEARCH PROCESS

The main goal of the search is to find existing works on three usability sub-characteristics (user interface aesthetics, learnability, appropriateness recognisability), and two quality in use characteristics (satisfaction and effectiveness) in educational applications and refine the search until the relevant information is acquired as below.

1) *Initial search in online database repositories*: The search used the tools that include Engineering Village and End Note X7 with search strings.
2) *Organise and categorise papers according to the selected resources in major indexing databases*: The study selected the main digital repositories or resources that include Science Direct, ACM, IEEEXplore, SpringerLink, Academia, and CiteSeerX.
3) *Record search results:* The results were recorded and classified for further analysis by search strings, resources, and the year of publication.
4) *Refine search*: Organised, categorised, and refined the search based on the defined quality characteristics and sub-characteristics.

Several steps were taken to accomplish the search of information using an iterative technique from the initial step to the refined step and several keywords were defined as listed in Table 4. The filter icons in the indicator column in Table 4 are used to represent each of the search keywords. Different colours are assigned to each indicator and later used in the articles selection process diagram when reporting the results.

TABLE 4. Search keywords.

Code	Description	Indicator
K1	User interface aesthetics	
K2	Learnability	
K3	Appropriateness recognisability	
K4	Satisfaction	
K5	Effectiveness	
K6	Usability	
K7	Technique or Approach	

The defined keywords were the terms used in the search process.

The search by publications from digital repositories considered each article title, its abstract and contents. It was derived using a string with a combination of keywords as listed in Table 5.

TABLE 5. Search strings.

Code	String
S1	educational application AND user interface aesthetic
S2	educational application AND learnability
S3	educational application AND appropriateness recognisability
S4	educational application AND satisfaction
S5	educational application AND effectiveness
S6	educational application AND usability
S7	educational application AND (technique OR approach)

The total and percentage of articles derived for each search string (S1 to S7) is listed in Table 6.

TABLE 6. Initial search result for each resource and string.

Resource	S1	S2	S3	S4	S5	S6	S7	Total (%)
Science Direct	79	283	278	152	87	276	303	1,458 (10.29)
ACM	156	433	388	176	98	356	472	2.079 (14.67)
IEEEXplore	834	942	751	506	642	1209	971	5,855 (41.33)
SpringerLink	68	252	206	377	37	389	560	1,889 (13.33)
CiteSeerX	18	25	310	198	24	357	205	1,137 (8.03)
Academia	56	67	498	147	81	455	446	1,750 (12.35)
TOTAL	**1211**	**2002**	**2431**	**1556**	**969**	**3042**	**2957**	**14,168 (100)**

Fig. 3 illustrates the percentage of articles found during the initial search stage. IEEEXplore contributes the highest that is 41.33% from the total articles, while CiteSeerX only represents 8.03% from the total of 14,168 articles.

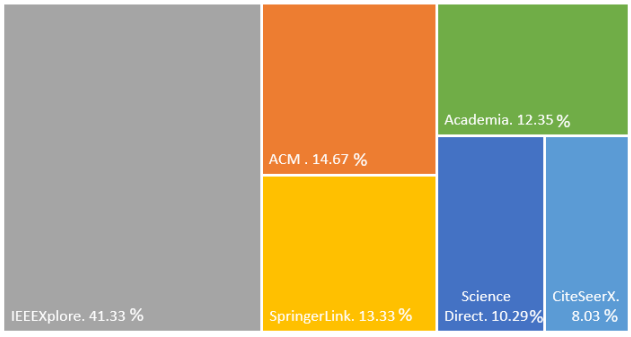

FIGURE 3. Percentage of articles selected based on keyword strings and resources.

C. INCLUSION AND EXCLUSION CRITERIA

In this SLR step, several criteria should be considered before the articles can be included or excluded. Firstly, the articles must be sorted based on the resources as in Table 6. Secondly, the articles must be written in English or they can be translated directly using Google Translate. The selected articles must meet the concerned fields, which are educational applications, computer science, human-computer interaction, and software engineering. Finally, the selected articles must meet the search strings as listed in Table 5. Thus, the articles that did not meet the inclusion criteria were excluded from this study. Regarding the exclusion criteria, articles that contained the search keywords but were not in relevant fields, were also excluded.

D. QUALITY EVALUATION

To confirm with the quality of the selected articles, Table 7 is produced as the guideline to select relevant articles based on the formulated RQs. For each RQ, it should answer either fully (yes) or partially. Those not answering the RQ (no) were excluded. Those articles that answered partially were further evaluated for inclusion or exclusion. Fig. 4 illustrates the evaluation process flow on how the articles were evaluated to determine its quality.

TABLE 7. Evaluation based on research questions.

Research Question	Answer
RQ1: Do the articles clearly discuss user interface aesthetics, learnability, appropriateness recognisability, satisfaction, and effectiveness in educational applications?	[Yes/No/Partially]
RQ2: Are the techniques or approaches clearly defined in the research?	[Yes/No/Partially]
RQ3: Do the articles discuss the gaps in the existing works?	[Yes/No/Partially]

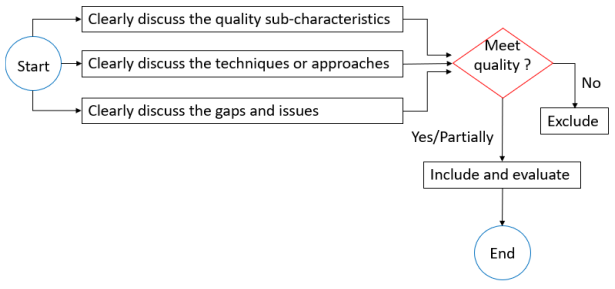

FIGURE 4. Evaluation process flow.

The classification was used to further evaluate the articles as below:

1) Clearly discuss the five concerned software quality in educational applications: user interface aesthetics, learnability, appropriateness recognisability, satisfaction, and effectiveness.
2) Clearly mention techniques or approaches in their research.
3) Clearly discuss the gaps and issues.

Some of the articles partially met the evaluation process. Further selection was executed by the researchers to validate whether such articles should be included or not to get relevant information for the concerned software quality in educational applications.

IV. RESULTS

The SLR process had systematically reviewed the concerned two quality in use characteristics (effectiveness and satisfaction) and three usability sub-characteristics (user interface aesthetics, learnability, appropriateness recognisability) in developing educational applications. As mentioned in the search strategy, the search process started with the initial step based on the keywords stated in Table 4. In the initial stage, normally search by keywords produce a large volume of articles because the results consist of articles from other fields that match the keywords.

For instance, the search keyword K1 (user interface aesthetics) in the educational domain, the initial search retrieved 1,211 articles. After refining the search, only 43 articles were selected to be evaluated in the inclusion/exclusion step. Finally, only eight articles were selected. The same process was done for other search keywords (K2 to K7).

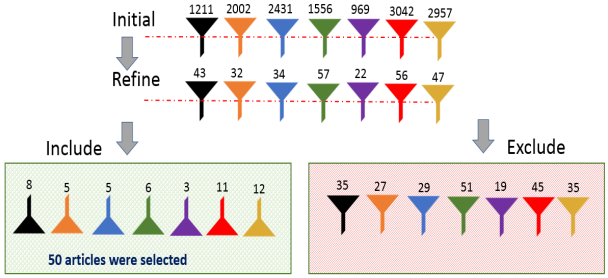

FIGURE 5. Selection process.

Fig. 5 shows the search process from the initial step followed by the refinement step. Finally, only 50 articles were included in this study as listed in Appendix A. Besides the diagram in Fig. 5, the line chart in Fig. 6 presents the derived data clearly as also used in other works [41], [42]. The works listed in Appendix A indicate the main keywords found based on respective search strings (shaded, ticked cell) while other keywords found when studying the articles are also ticked but not shaded.

The data from the selection was calculated for the percentage and illustrated using a line chart as in Fig. 6. At the initial search (blue line), K6 (usability) has the highest percentage of articles (21.47%) while K5 (effectiveness) has the lowest (6.84%). After the search process is refined, the inclusion stage (orange line) shows that K7 (approach) has the highest score (24%) while K5 (effectiveness) scores even lower (6%) than the initial stage.

The results are further discussed in Section V. The selected articles that directly focus on each of the search strings are also listed in Table 8. It shows the highest number of articles (12 out of 50) are based on S7 search string that is

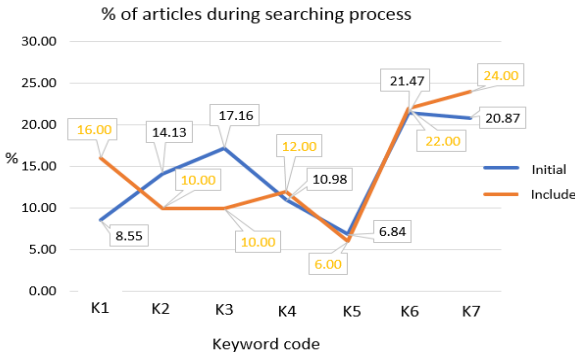

FIGURE 6. Percentage of articles selected based on keyword codes.

TABLE 8. Selected articles by search strings.

Search String	Selected Articles	Total
S1	[43][44][45][46][47][48][49][50]	8
S2	[51][52][53][54][55]	5
S3	[56][57][58][59][60]	5
S4	[61][62][63][64][65][66]	6
S5	[67][68][69]	3
S6	[8][24][25][26][27][32][34][35][37][38][40]	11
S7	[7][70][71][72][73][74][75][76][77][78][79][80]	12
	Grand Total	**50**

"educational application AND (technique OR approach)" followed by S6 (total = 11) and S1 (total = 8).

The percentage of articles for each keyword as listed in Table 9 is reduced in a non-symmetric pattern from the initial to its final step. It is because some papers do not meet the concerned research fields. In addition, our study only considers the recent articles that are published from 2015 until the first quarter of 2020 ($N = 50$) as in Fig. 7.

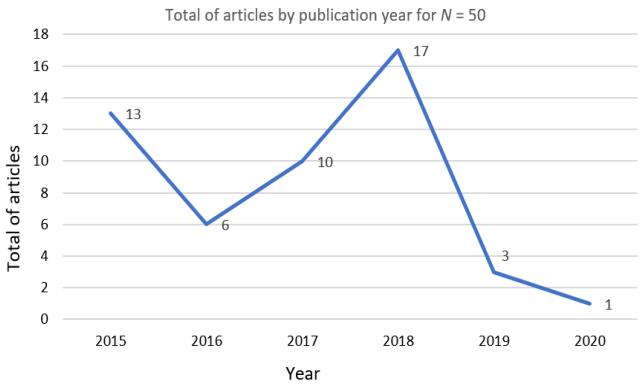

FIGURE 7. Total of articles by publication year.

The search process recorded the number of articles after each step (initial, refine, include, and exclude) as shown in Fig. 5. To prove the recorded numbers are significant and reliable, we investigated and calculated the correlation value for the relationship and the Cronbach's alpha for the reliability as suggested by Creswell [81].

TABLE 9. Analysis of correlation, cronbach alpha and regression for the SLR activity.

Part A: Percentage of articles for each search step

	Initial		Refine		Exclude		Include	
	Article	%	Article	%	Article	%	Article	%
K1: User interface aesthetics	1211	8.55	43	14.78	35	14.52	8	16.00
K2: Learnability	2002	14.13	32	11.00	27	11.20	5	10.00
K3: Appropriateness recognisability	2431	17.16	34	11.68	29	12.03	5	10.00
K4: Satisfaction	1556	10.98	57	19.59	51	21.16	6	12.00
K5: Effectiveness	969	6.84	22	7.56	19	7.88	3	6.00
K6: Usability	3042	21.47	56	19.24	45	18.67	11	22.00
K7: Technique or Approach	2957	20.87	47	16.15	35	14.52	12	24.00
Total	14168		291		241		**50**	

Part B: Calculation of correlation coefficient and Cronbach's Alpha value

	Initial	*Refine*	*Exclude*	*Include*
Initial	1			
Refine	0.4549	1		
Exclude	0.3222	**0.9761**	1	
Include	0.7182	0.7060	0.5352	1
Upper value for correlation coefficient value =				**0.9761**
Mean for correlation coefficient value =				**0.6188**
Standardized Cronbach's Alpha value =				**0.8665**

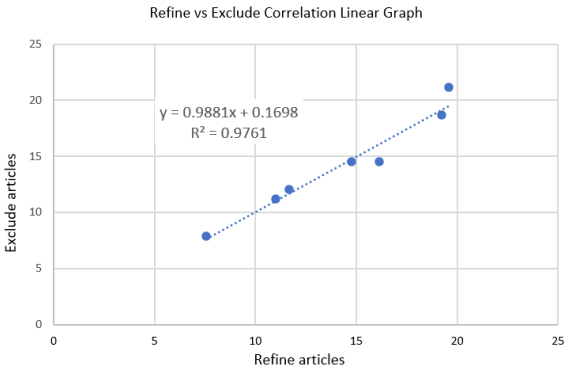

Table 9 is divided into two parts: Part A calculates the percentage of recorded articles. The percentage value was used for further calculation, as stated in Part B. Two values were calculated, which were correlation coefficient and Cronbach's Alpha. This study adopts Pearson's correlation coefficient to measure the strength of the linear relationship [82] between search steps.

The correlation value is from -1 to 1, where value 1 represents a perfect positive correlation. The closer a value to 1, the stronger the relationship between the two variables [83]. The correlation coefficient calculation derived all valid values between -1 to 1. It shows that a correlation exists for the search process. Four out of six values show more than 0.5, where three of them show a value near 1 [84]. There is a strong correlation between refine and exclude steps that has a high value of $R^2 = 0.9761$.

The Cronbach's alpha values were calculated, and they typically range from 0 to 1 [81]. Values closer to 1 indicate a greater internal consistency of the variables on the scale. In other words, a higher Cronbach's alpha value shows a greater scale of reliability. Cronbach's alpha, also known as coefficient alpha, is a measure of reliability, especially internal consistency reliability or item interrelatedness of a scale or check [81]. Internal consistency refers to the volume that each item on the scale or test contributes positively towards measuring the equal assemble. The simplified method for Cronbach's alpha (α) is as follows:

$$\alpha = (N \cdot \bar{c})/[\bar{v} + (N-1) \cdot \bar{c}]$$

where N is the variety of scale or objects, $\bar{c}$ is the average inter-object covariance for some of the scale items, and $\bar{v}$ is the common variance. Cronbach's alpha commonly stages from 0 to 1. Values in the direction of 1.0 imply an extra inner consistency of the variables on the scale. In different phrases, better Cronbach's alpha values display greater scale of reliability. This study has shown a Cronbach's alpha value of $\alpha = 0.8665$, and we can conclude that the process has a greater scale of reliability.

V. DISCUSSION

The selected articles as reported in Section IV were derived from the SLR to answer the RQs as listed in Table 7. The percentage of the articles were calculated, and we found that 54% of the articles answered RQ1, 22% answered RQ2 and 24% answered RQ3 as shown in Table 10.

TABLE 10. Percentage of articles answering each research question.

Research Question	$N = 50$	%
RQ1: Do the articles clearly discuss user interface aesthetics, learnability, appropriateness recognisability, satisfaction, and effectiveness in educational applications?	27	54
RQ2: Are the techniques or approaches clearly defined in the research?	11	22
RQ3: Do the articles discuss the gaps in the existing works?	12	24

A. RESEARCH QUESTION 1 (RQ1)

RQ1 is stated as ''Do the articles clearly discuss user interface aesthetics, learnability, appropriateness recognisability, satisfaction, and effectiveness in educational applications?''. To answer RQ1, this study includes the articles with YES and PARTIALLY answers.

TABLE 11. Code for characteristic or sub-characteristic by frequency.

Code	Description
1 sub-C	One characteristic or sub-characteristic was discussed
2 sub-C	Two characteristics or sub-characteristics were discussed
3 sub-C	Three characteristics or sub-characteristics were discussed
4 sub-C	Four characteristics or sub-characteristics were discussed
5 sub-C	Five characteristics or sub-characteristics were discussed

Table 11 lists the codes that are given to tag each article with the frequency of characteristics or sub-characteristics covered in the articles, from one (*1-sub-C*) to five (*5 sub-C*). Fig. 8 shows the percentage of articles by the given codes. About a third of the articles (33.33%) discussed two characteristics or sub-characteristics in their works, while only 3.70% of the articles discussed covering four of them.

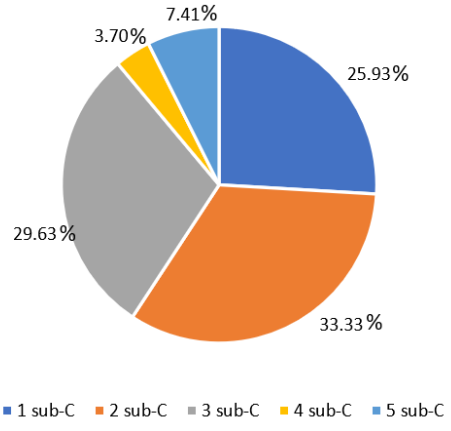

FIGURE 8. Percentage of articles by frequency 1 to 5.

Only two articles (7.41%) out of 27 selected articles discuss all the five characteristics or sub-characteristics (*5 sub-C*). In the first study, students who learned using Papora application showed that they were satisfied because the lesson could be easily understood and learned [43]. Another researcher mentioned that design aesthetics is one of the greater degrees of satisfaction that leads to a greater degree of loyalty [44].

Only one article (3.70%) discusses four of the concerned software qualities (user interface aesthetics, learnability, appropriateness recognisability, and effectiveness) (*4 sub-C*). The study concludes that educational applications that implement user interface aesthetics are enjoyable, learnable, engaging teaching strategies in learning, and effective in enhancing students' understanding of the taught contents in the concerned lesson [45].

There are eight articles (29.63%) that partially discuss three characteristics or sub-characteristics (*3 sub-C*). A study states that user interface aesthetics are often defined as a subjective matter related to the concept of ''beauty'', ''visual design'', and ''appealing''. They are considered as key factors with the perceived usability of the user satisfaction and the effective usability [46]. Another work mentions that aesthetics is a subjective quality referring to graphic design, overall visual appeal, colour scheme, and stylistic consistency, which lead to user satisfaction, and support on users' learnability [47]. Hence, aesthetic can improve students' learnability because they can understand in real-time [48].

Learning to use applications is essential for human development. Knowledge will be increased from day to day and becomes easier to understand effectively [49]. Learnability is where applications are effectively learned by all levels of users. User satisfaction and effectiveness of the applications are achieved when the applications successfully help users in doing their tasks [50]. Hence, satisfaction is a vital indicator for user experience because it is constantly connected with changes in user interests towards applications that act as personal assistants to understand users' intent and closely related to execute tasks accurately and completely (effectiveness) [51].

Furthermore, effective applications help users to easily understand each process when completing a given task in a short period of time with quick learning. Effectiveness involves the process from beginning until the end of an application usage [52]. Therefore, other criteria or factors need to be measured together such as using heuristic evaluation and query technique in order to evaluate the understandability and learnability for an application with good effectiveness [53].

In addition, nine articles (33.33%) discuss only two characteristics or sub-characteristics (*2 sub-C*). A study shows that information aesthetics in educational applications include information visualisation and generative art could contribute to learning experiences and support the learning technique [54]. Graf *et al.* [55] mention that the learning process will improve memorability because it enables learners to reproduce images or concepts or repeat the exact words or contexts. Another study states that aesthetics elements and the usability of the system aim to motivate education or modify users' behaviour in improving their understanding on the learning process [56]. Hence, the ''self-efficacy'' subscale explores students' confidence in their ability to understand course contents. Learning motivation will develop students' deeper knowledge and skills [57], [58].

While Project-Based Learning technique is conducted to understand how knowledge interacts with the self-esteem and with the self-actualisation of the students' understandability that motivates students in their learning process [59]. Guttmann's method is effective for composing questionnaires because it puts the results of the questionnaire on a scale [60]. Another work on 3D mathematics model and computer coding offers reliable information for students to increase their understandability and assist their learnability [61], [62].

Finally, seven articles (25.93%) discuss only one sub-characteristic (*1 sub-C*). A work found that students of a mental health education course who used mobile informatisation teaching model showing higher satisfaction besides improving their mental health [63]. There is also an analysis on the teachers' ability to teach using their selected approach in order to measure students' learnability [64].

In term of students' satisfaction, it is important to get students' attention and confidence which are relevant to the subject course content [65]. In addition, satisfaction is divided into three categories which are human factors such as skill, intrinsic value such as interest, and user requirements such as interactive [66]. A study reports the use of Peer Assessment tool where students found the structure of the given rubric was complicated due to inconsistency of the information arrangement [67]. Meanwhile, illustration of the lesson using promising scenarios could empower digital applications in term of learnability together with better memorisation and learning [68]. While another experiment using ''cost-constrained'' interaction framework shows that the degree of satisfaction correlates with users' perception such as the content and the quality of product besides their self-interests [69]. Fig. 9 concludes the findings for RQ1.

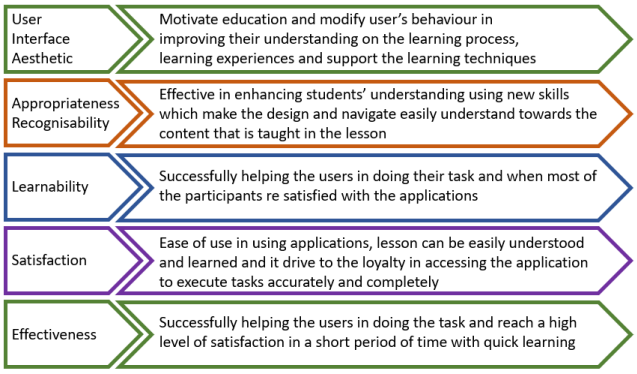

FIGURE 9. Summary of findings for reviewed software quality.

B. RESEARCH QUESTION 2 (RQ2)

RQ2 is stated as ''Are the techniques or approaches clearly defined in the research?''. From the selected articles, there are 12 out of 50 articles that clearly mention their proposed works in their research as depicted in Fig. 10. The works can be classified as component-based, case-based, design-based, or model-based.

Component-based has been popular among software developers and is basically used to investigate the impact of

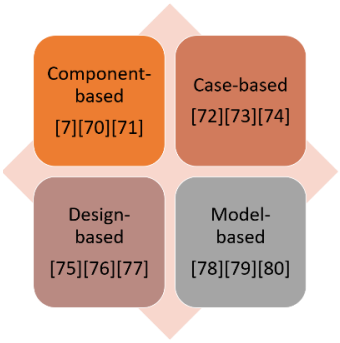

FIGURE 10. Techniques or approaches in current works.

updates in applications [7]. Applications that consist of many components must function well and must be reliable [70] in a natural and progressive manner [71]. In addition, a case-based technique involves the use of cases or case by case basis, and manages imperfection using belief function theory [72]. Normally, it refers to past plan cases to assist in initial findings for a new project [73]. A case-based technique supports the understanding and prescribing potential arrangements as preventive and/or remedial measures [74].

Another technique is design-based. For instance, it builds the multifaceted nature of deformity examination and audit ability to produce and acquire information that has improved exponentially [75], [76]. Hence, it helps software developers to change the manual or half manual working style into a completely programmed task [77]. On the other hand, adaptation of a model-based technique may give the idea to improve applications as compared to the previous versions [78]. Besides, it allows developers to decouple the adaptation rules from the architecture. Thus, software developers can easily change one of these models without affecting the others [79]. Hence, design-based technique satisfies the necessities of the developers' skills by referring to previous process or documentation [80].

C. RESEARCH QUESTION 3 (RQ3)

In order to address RQ3 that is ''Do the articles discuss the gaps in existing works?'', this study depicts that some of the selected articles mention the gaps of existing works under the introduction, discussion or future work subsections.

A study deduces that software developers focus more on design aesthetics, which is believed to be one of greater degrees of satisfaction that leads to a greater degree of loyalty [64]. Another work reports that the assessment structure of a rubric is complicated due to inconsistency of information arrangement [21]. User satisfaction and effectiveness of the application are achieved when the application is successful in helping users in doing their tasks and reach a high level of satisfaction [72].

Another issue highlighted is related to receiving inconsistent instructions during development and absence of methods to evaluate competency achievement effectively [3]. Finally,

TABLE 12. Existing works as the results of the SLR.

No.	Existing Work	Author (Year)	Search Keyword							Summary
			K1	K2	K3	K4	K5	K6	K7	
1	Mobile Banking Applications [43]	Mkpojiogu et al. (2016)	√	√	√	√	√			Design aesthetics is one of the greater degrees of satisfaction that leads to a greater degree of loyalty and has the potential to ginger user satisfaction, understandable, learnable and easy to use.
2	Multidisciplinary approach [44]	Ramdhani and Ramsaroop (2015)	√	√	√		√			Aesthetics in educational applications is enjoyable, learnable, and engaging teaching strategies in active learning. Its effectiveness enhances students' understanding of the content that is taught in the lesson.
3	Inter-subjectivity of judgement [45]	Zen and Vanderdonck (2016)	√			√	√			User Interface aesthetics are often defined as a subjective matter related to the concept of "beauty", "visual design" and "appealing". They are considered as key factors having a direct relation with the perceived usability of the user satisfaction and the effective usability.
4	Mobile Apps Rating Scale (MARS) [46]	Larco et al. (2018)	√	√		√				Aesthetics is a subjective quality referring to the graphic design, overall visual appeal, color scheme, and stylistic consistency, which lead to user satisfaction and support on users' learnability.
5	Aesthetic Education Environment [47]	Gao (2018)	√	√	√					Aesthetic applied in a class when teaching can improve students' learnability because students can timely understand in real-time.
6	E-diary [48]	Gogh et al. (2017)	√	√	√		√			The continuous learning process is essential for human development because knowledge will be increased from day to day and it becomes easier to understand the educational processes effectively.
7	Construction Defect mobile application (app) [49]	Nasruddin et al. (2018)	√	√		√	√			Learnability is where applications can be effectively learned by all levels of participants. User satisfaction and effectiveness of the applications are achieved when the applications are successfully helping the users in doing their task and when most of the participants are satisfied with the applications.
8	Intelligent Personal Assistant (IPA) Application [50]	Babic et al. (2018)	√	√	√	√	√			Satisfaction is the indicator of user experience because it is constantly connected with changes in user interests towards the applications for personal assistants to understand users' intent, which are closely related to execute tasks accurately and completely (effectiveness).
9	OLab system [51]	Prabhakaran et al. (2018)		√	√		√			The effective applications help users to easily understand each process during completing a given task in a short period of time with quick learning. Effectiveness involves process from the beginning until the end.
10	Case-based performance comparison [52]	Felix et al. (2016)		√	√		√	√		In order to test on the understandability and learnability of the applications that have a good effectiveness, several other criteria or factors need to compile together during evaluation such as heuristic evaluation and query technique.
11	Optimization Technology and Application of BIM [53]	Zhang and Meng (2017)		√	√					Information aesthetics in educational applications, which cover information visualization and generative art contribute to learning experiences and support the active learning technique.
12	Gamified Online System (SiGMa) [54]	Toda et al. (2015)		√			√			Aesthetics elements and the usability of the system aim to motivate education or modify users' behavior that aids and improve their understanding in the active learning process.
13	Mobile Virtual Museum [55]	Graf et al. (2015)		√	√					The learning process will improve memorability because it enables us to reproduce images or concepts or repeat the exact words or contexts, can understand their use, the place they belong to and experience the "hidden" stories behind it instead of just gaining a deeper understanding of the object while being both entertaining and educating.
14	5E Mobile Inquiry Learning Approach [56]	Cheng et al. (2016)		√	√					The "self-efficacy" subscale explores students' confidence in their ability to appropriateness recognisability in the content of the course. Motivation in learning will develop students' deeper knowledge and skills.
15	Self-regulatory learning behaviours [57]	Finn (2020)		√	√	√				Focusing on the association of inspiration and discernment can give extra bits of knowledge into the component's fundamental, self-administrative learning practices which include the past accomplishment encounters and can improve our comprehension of the elements that impact accomplishment decisions
16	STEM [58]	Kuo et al. (**2019**)		√	√				√	Developing a human-computer interaction (HCI) system to resolve real-world issue involves skills and STEM knowledge
17	Project-Based Learning (PjBL) [59]	Seman et al. (2016)		√	√					PjBL conducted to understand how knowledge interacts with the self-esteem and with the self-actualization of the students' understandability (appropriateness recognisability) that motivates students in the learning process.
18	Guttmann's method [60]	Retnani et al. (2017)		√	√					Guttmann's method is effective for composing questionnaires because it puts the results of the questionnaire on a scale. Results show that applications are learnable and easily to understand as well as to identify information found on the applications.
19	3D Printing [61]	Sun and Li (2017)		√	√	√				3D model and computer coding offer reliable information for students to develop their understandability (appropriateness recognisability) and assist their learnability on the abstract concept of mathematics
20	Deep Learning [62]	O'Mahony et al. (2019)				√				Benefit of this learning process is its compatibility with usual bags-of-features frameworks, allowing for cross reproductions assembly morphologic and improving their skill of knowledge
21	Mobile Informatization Teaching Model [63]	Zhao et al. (2018)			√	√				Students' mental health education course uses the mobile informatization teaching model and showed a higher satisfaction besides improving their mental health
22	ICT Application [64]	Jing-Lu and Guo-Dong (2018)				√				Understanding when using the ICT applications becomes a key during analysing the ability of the teachers' appropriateness recognisability in their lesson material and to measure the ability of the students' learnability in the learning session.
23	ARCS (Attention, Relevance, Confidence, and Satisfaction) motivation model [65]	Tsukamoto et al. (2015)				√				To compromise with students' satisfaction, besides a good application, learning environments such as teaching skills, number of support staff, and temperature of the room is important to get students' attention and confidence, which are relevant to the subject course content.
24	ICT tool [66]	Renée and Ghislain (2015)				√				Satisfaction factors are divided into three categories. Firstly, human factors such as skill and attitudes. Second is intrinsic value such as interest and joy and third is user requirement such as interactive.
25	Per Assessment Tool [67]	Ward and Jackson (2017)				√	√			Peer Assessment tool that shows students found the structure of the given rubric was complicated
26	Digital application [68]	Schobel et al. (2018)				√	√			Empower digital applications in term of learnability together with better memorisation and learning
27	Cost-Constrained Video [69]	Li et al. (2018)				√	√			Satisfaction is related to human skill, intrinsic value and user requirements
28	Stack Overflow [8]	Zou et al. (2015)	√					√	√	Awareness to define the NFRs at the early stage to avoid latent problems

the implementation should have overarching aims, which is a process of guidance (framework) that translates finding from a research into a process [50]. The highlighted gaps can be further explored to be solved in future by considering more quality characteristics when designing and developing educational applications.

TABLE 12. *(Continued.)* **Existing works as the results of the SLR.**

No.	Existing Work	Author (Year)	Search Keyword							Summary
			K1	K2	K3	K4	K5	K6	K7	
29	GOMS Model [23]	Rosyidah et al. (2019)						√	√	Ease of use of the application needs to be considered in various activities to manage numerous instructive components in educational applications
30	Process model [24]	Arteaga and Rivera (2018)					√	√		Structuring, creating, and assessing the educational applications require users' involvement to conform the usability characteristic and the necessary requirements have been fulfilled
31	MiESPE movil [25]	Delgado et al. (2018)						√		Educational applications that run on multiplatform must establish an effective communication within students. Heuristic evaluation reported that usability characteristics may differ for different educational applications based on the research scope
32	Technologies to support community-dwelling persons [28]	Meiland et al. (2017)				√	√	√		Technology field needs guidance to produce an effective application using a framework to assist the targeted audience
33	Cloud-based Data Management [31]	Al-Sumaty and Irfan (2018)	√	√	√	√		√		Inquiry-based learning activities must be proposed to increase users' especially students' understanding and satisfaction. The concept of visualizing may easily help student to understand the learning concept
34	Interaction Design for Senior High School Students [33]	Putra et al. (2018)		√				√		Usability can be described from a variety of factors including the interface design. While learnability does not only depend on exploring activities, but it should also include client desires.
35	Authoring Tools [34]	Roldán et al. (2016)	√	√				√		Learnability does not only depend on exploring activities
36	Cognitive load [36]	Yang et al. (2018)	√		√	√		√		Users applied short term memories, depending on the system user interface
37	Competency-based knowledge [37]	Zhang et al. (2017)	√		√			√		New knowledge and skills that involve various experiences and challenges
38	Decision Tree Analysis [39]	Alaa et al. (2018)	√		√	√		√	√	Ability to use technological tools, remember and recognise new knowledge
39-41	Component-based [69][70][71]	Turgeman and Smart (2018), Frincu (2015), Belhaj et al. (2015)							√	The function supports infrastructure items for an application but can be applied for over one application. The approach is a reusable object that speeds up application creation and delivery and provides additional options where every element can have its own quality attribute profile.
42-44	Case-based [72][73][74]	Ayed et al. (2017), Berriche (2015), Bennani et al. (2017)							√	This approach involves initial knowledge about new cases, and the learning capabilities on each case will adapt depending on new situations. Different aspects or stages of cases may also be viewed individually. Consequently, the effort to seek out relevant and similar expertise to a given state of the whole application can be considerably reduced.
45-47	Design-based [75][76][77]	Ke et al., (2015), Chen and Liu (2018), Gang et al. (2017)							√	The design will directly show the "users with precise needs" message to confirm that users are happy to complete the tasks successfully. To grasp the planning design, designers use their skills to develop each purposeful and aesthetic aspect of the UID, which may not be the standard UID.
48-50	Model-based [78][79][80]	Lu and Saniie, (2015), Gherardi and Hochgeschwender (2015), Prosvirin and Kharchenko (2015)							√	It shows the real work on presenting the flow of the system and the consequences for the re-engineering process. Implementing a model could be a distinctive task that needs a large quantity of observation and skill. In code implementation, time must be optimized, but device-specific libraries must be available.

Note: The shaded cells show the main keywords derived during the search while those not shaded are other keywords that were identified when studying the works

VI. CONCLUSION AND FUTURE WORK

Educational applications that are available in today's market can be further improved in motivating teachers' and students' overall satisfaction. Software developers especially novices, should clearly understand and be concerned about users' needs, and should be aware and define NFRs at the early stage of software development to avoid some latent problems that involve quality characteristics. This paper reports the SLR on the works that concern on user interface aesthetics, learnability, appropriateness recognisability, satisfaction, and effectiveness for educational applications.

The search process was conducted, and three research questions were formulated for the quality evaluation process. Only 50 articles were finally selected and the results for each quality characteristic or sub-characteristic were discussed by focusing on the five concerned software quality. The computation of the correlation value, the Cronbach's Alpha value, and the p-value demonstrates that a correlation exists, and the reliability of the extracted data during the search activity achieved the expected level.

The results and discussion reflect that current works consider various quality characteristic or sub-characteristics in educational applications. However, only two studies discuss all the five. Existing approaches or techniques that have been applied in application developments can still be improved by adapting more quality characteristics or sub-characteristics and measure the related factors accordingly. It also shows that existing works on the five concerned software quality focus on users' and developers' point of view, as well as user interface design in relation to NFRs.

Future work will be to propose a framework that focuses the quality from developers' point of view. The framework will provide a guidance to developers on how to improve the five concerned software quality that are user interface aesthetics, learnability, appropriateness recognisability, satisfaction, and effectiveness when developing educational applications.

APPENDIX

See Table 12.

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