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Evaluation of learning object reusability and compatibility in e-Learning systems using a collaboration of object-oriented metrics and SCORM standard methods

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ABSTRACT

Penelitian ini bertujuan untuk mengevaluasi sistem e-Learning of the Standardization and Conformity Assessment dalam aspek penggunaan kembali objek pembelajaran dan kompatibel di berbagai sistem e-learning menggunakan kolaborasi metode pengukuran object-oriented metrics dan standar Shareable Content Object Reference Model (SCORM) sebagai standar yang banyak digunakan pada pengujian konten tersebut disusun, disimpan, dan diakses. Tahapan penelitian yang dilakukan yaitu melakukan studi literatur, kemudian pengumpulan data, lalu mengukur penggunaan kembali dengan object-oriented metrics yaitu Cohesion, Coupling, Size, dan Complexity, Educational Portability serta Technical Portability pada objek pembelajaran berbasis Shareable Content Object Reference Model (SCORM). Nilai kohesi berkisar antara 0,27 hingga 0,86, berada dalam kisaran sedang hingga tinggi yang menunjukkan bahwa elemen-elemen dalam objek pembelajaran terhubung dengan cukup baik. Nilai kopling berkisar antara 0,20 hingga 0,75, berada dalam kisaran sedang hingga rendah, yang menunjukkan bahwa desain sistem cenderung relatif independen, yang menunjukkan desain yang modular dan dapat digunakan kembali. Hasil untuk variabel ukuran juga memperlihatkan bahwa objek pembelajaran berada pada ukuran sedang hingga baik untuk objek pembelajaran yang dapat digunakan kembali. Penelitian ini mengungkapkan bahwa untuk meningkatkan educational portability, objek pembelajaran harus memiliki keseimbangan antara Cohesion, Coupling, Size, dan Complexity, dengan mempertimbangkan karakteristik setiap jenjang pendidikan. Temuan ini diharapkan memberikan kontribusi dalam pengembangan sistem e-learning yang lebih fleksibel dan efektif di berbagai konteks pendidikan.

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1. INTRODUCTION

The advancement of information technology has transformed the paradigm of education globally, including the development of e-learning. E-learning, or electronic learning, is a learning method that leverages digital technology to deliver educational materials in a flexible, interactive, and easily accessible manner [1]. With the ability to provide learning that is not constrained by time or location, e-learning has become one of the most effective solutions for improving access to education, especially in today's digital era.

One of the key elements in e-learning systems is learning objects. Learning objects are modular units of educational materials, such as videos, quizzes, documents, or simulations, designed to be reused in various learning contexts [2]. With their modular and flexible nature, learning objects allow educators and institutions to save time, costs, and effort in developing new materials, while also providing a more consistent learning experience for learners [3].

To ensure that learning objects can be reused and are compatible across various e-learning systems, certain standards are required to govern how the content is structured, stored, and accessed. One widely used standard is the Shareable Content Object Reference Model (SCORM) [4]. SCORM is a technical specification that ensures the interoperability, accessibility, and sustainability of learning objects across different Learning Management Systems (LMS). With SCORM, learning objects can be integrated into various e-learning platforms without significant modifications, thereby supporting the efficiency and effectiveness of the learning process [5].

Although SCORM offers numerous advantages, its implementation and utilization often face challenges. These challenges include limited understanding of SCORM specifications, insufficient evaluation of the effectiveness of SCORM-based learning objects, and the alignment between the design of learning objects and user needs. Without systematic evaluation, the full potential of SCORM in supporting the reuse of learning objects cannot be optimally realized [6].

This study aims to evaluate the reuse of SCORM-based learning objects within e-Learning of the Standardization and Conformity Assessment. The evaluation includes an analysis of interoperability, effectiveness, and efficiency in supporting learning objectives. The findings of this research are expected to provide new insights and practical recommendations for improving the development and utilization of SCORM-based learning objects, thereby supporting the sustainability of more innovative and inclusive e-learning systems.

2. METHOD

Learning objects are intended as building blocks that can be combine in many ways to construct collections that might be called lessons, modules, courses, or even curricula. So, author define the objects on the e-learning system as the learning object that will be evaluated and assessed [7].

The object itself are the whole courses and quizzes, the learning material within the system that presented in the e-book or PDF format and multimedia video will be reviewed. The objectives of the learning material will also be evaluated. The data will be later proceeded with implemented metric and the result will be analyzed and compared with reusability factors [8].

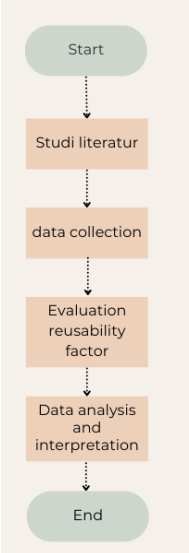

Figure 1. Stages of the research

At the literature study stage, an in-depth study of SCORM, the concept of learning objects, and evaluation metrics (Cohesion, Coupling, Size, Educational Portability, and Technical Portability) is conducted. Identifying previous research related to SCORM-based learning object evaluation. In the data collection stage, the activities carried out are collecting technical and descriptive information from each learning object, such as file format, size, and SCORM metadata, testing the integration of learning objects into the SCORM-based e-Learning of the Standardization and Conformity Assessment . In the 3rd stage, namely evaluating the reusability factor, the explanation of the metric variables and indicators can be seen in Table 1. The last stage,

we identify the strengths and weaknesses of the learning object based on the five metrics and linking evaluation results with SCORM standards and learning objectives.

The research model of this study describe in figure 2 which contain the relationship between reusability factors and reusability metrics [9]. It consists of several variables which is called metrics that lead to the results of this study. This study uses five variables or metrics that have been modified from the model of object oriented reusability model on previous study, namely: Cohesion, Coupling, Size, Educational portability, and Technical Portability [10].

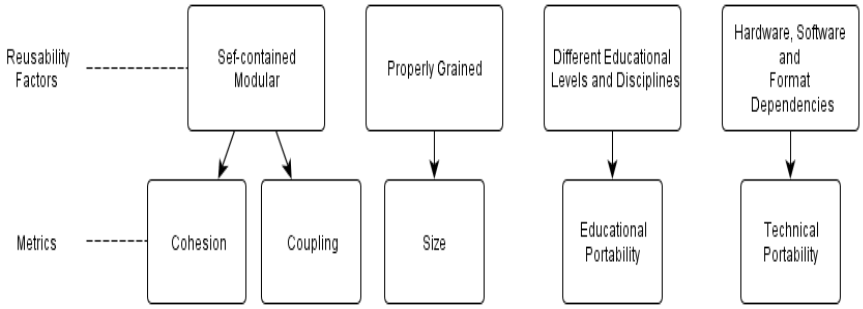

Figure 2. Research model relationship

All variables will be made into several indicators. Explanation of variables and indicators can be seen in Table 1.

Table 1. Variables and indicators

No	Variable	Indicators
1	Cohesion	Relationship link within learning object
2	Coupling	Dependencies link between learning object
3	Size and Complexity	Learning Object Size and Complexity
4	Educational Portability	Registered participant education levels
5	Technical Portability	Statistic Data from log file related to number of devices, browser, and operation system that user used to run the learning objects

The limitations of the method used include that the rigid SCORM standard can greatly affect the value of the reusability metric, partly because SCROM does not support personalization or automatic adaptation based on individual learning needs, thus reducing the flexibility and effectivity of its use in various educational contexts.

3. RESULT AND ANALYSIS

3.1. Learning Object Review

Based on SCORM 2004 definition, “learning objects are intended as building blocks that can be combine in many ways to construct collections that might be called lessons, modules, courses, or even curricula”, the object such as a course and a learning module will be taken as the learning object that will be reviewed [11]. On the e-Learning of the Standardization and Conformity Assessment can be seen in figure 3, there are 18 learning objects based on SCORM definition, which will be mapped into the class diagram to see the correlation between learning objects [12].

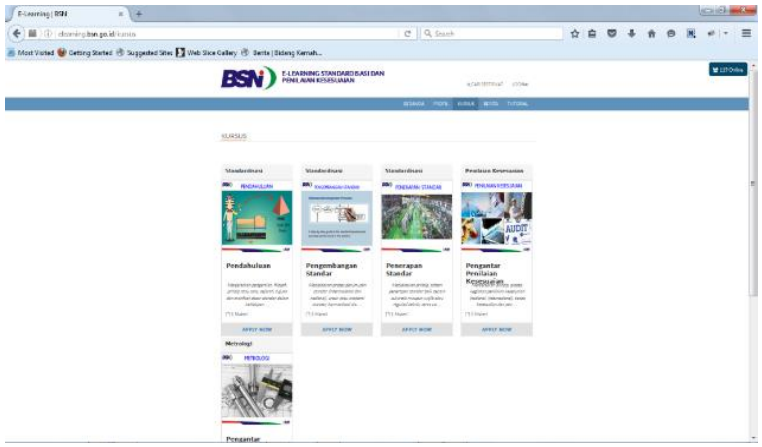

Figure 3. Standardization and conformity assessment e-learning website

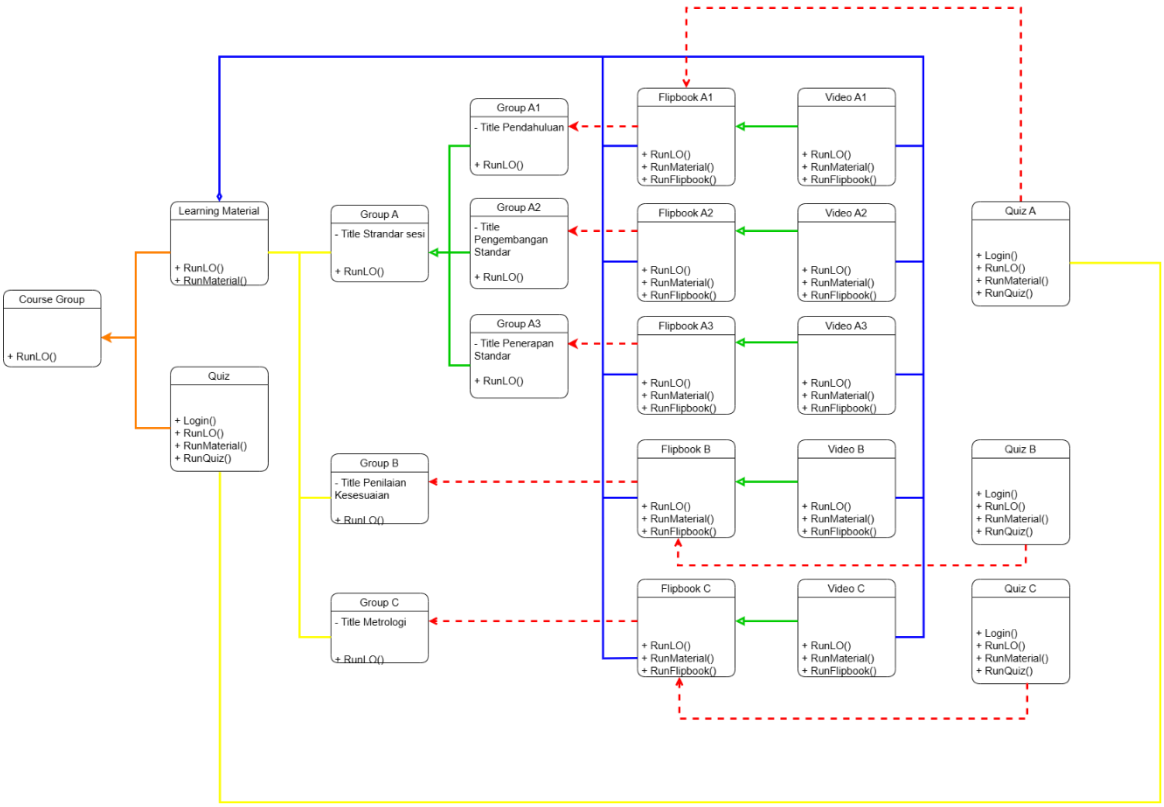

Figure 4. Learning object class diagram

Those correlation will be used to obtain the value for Cohesion and Coupling variable. From the figure 4 can be seen that course group composed from Learning materials and Quizzes [13]. The learning material aggregates into two types, Learning material form in a flipbook and form in a multimedia video. The learning materials associates with courses group, so each courses have its own flipbook and video [14].

Learning video itself inherited from flipbook because it's another form of the learning material taken from the e-book. For the quizzes, it associate with each quizzes in the courses group. Standardization Course Group inherits into three single course. Every learning material form dependent on the courses and the quizzes dependent on learning materials [15].

3.2. Cohesion

Adapted from object-oriented metrics, to measure the value of cohesion is by measuring the extent to which elements in a learning object or module are logically interrelated and support the same learning objectives [16]. In the context of SCORM-based learning object evaluation, this metric is used to assess Learning objectives, Learning materials (text, video, quiz, or simulation), Supporting activities (exercises,

evaluation) [17]. The higher the level of cohesion, the better the elements support each other in achieving a particular learning objective. As an example, the learning object Course A1 has 1 objectives, 3 features and 2 activity to access the course A1. Overall value can be seen on table 2.

Table 2. Learning object attributes value

LO	Learning Objectives Value (α)	LO Materials Value (m)	LO Activity Value (μA)	Cohesion Value
Courses A1	1	3	2	0.50
Courses A2	1	3	2	0.70
Courses A3	1	3	2	0.36
Courses B	1	3	2	0.86
Courses C	1	3	2	0.50
Quiz A	1	6	7	0.27
Quiz B	1	6	5	0.51
Quiz C	1	6	5	0.75
Flipbook A1	1	11	3	0.71
Flipbook A2	1	11	3	0.63
Flipbook A3	1	11	3	0.82
Flipbook B	1	11	3	0.57
Flipbook C	1	11	3	0.69
Video A1	1	7	3	0.72
Video A2	1	7	3	0.61
Video A3	1	7	3	0.74
Video B	1	7	3	0.65
Video C	1	7	3	0.70

The cohesion values range from 0.27 to 0.86, indicating variations in the degree of relatedness of the elements in the learning object. Most of the cohesion values are in the medium to high range. This indicates that the elements in the learning object are reasonably well connected, although there are some low values. A low value of 0.2 can lead to a less effective learning experience as the elements do not support each other. A high cohesion value of 0.86 indicates that the elements support each other and focus on clear objectives including specific learning objectives, but needs to be balanced with low coupling to avoid over-dependency.

3.3. Coupling

A reusable learning object must be less coupling between each other. The more coupled it is, the harder it will be reused because if there's any change from one object, it will influenced another object. So, the learning object must be self-contained with low value of coupling [18]. From the object oriented coupling fundamentals, object X is coupled to object Y if and only if X send message to Y, if not, then there's no coupling link [19]. For example, Course Group A1 associated with learning material, which means it has 1 link connected. All coupled value can be seen on table 3.

Table 3. Learning object link value

LO	Value of Coupling
Courses A1	0.45
Courses A2	0.60
Courses A3	0.30
Courses B	0.75
Courses C	0.40

Quiz A	0.20
Quiz B	0.44
Quiz C	0.65
Flipbook A1	0.62
Flipbook A2	0.55
Flipbook A3	0.72
Flipbook B	0.48
Flipbook C	0.60
Video A1	0.63
Video A2	0.52
Video A3	0.65
Video B	0.55
Video C	0.60

The resulting coupling values range from 0.20 to 0.75, indicating variations in the level of dependency between elements in the learning object. A low value of 0.20 means that the elements in the system are relatively independent, indicating a modular and reusable design. The system is ideal for supporting flexibility and interoperability across different e-learning platforms. A high value of 0.75 means that elements are highly dependent, which can limit flexibility and reusability. This indicates an inefficient system design that is difficult to reuse, requiring improvements to the element architecture. Most coupling values are in the medium to low range, indicating that the system design tends to be modular.

3.4. Size and Complexity

The size and complexity of the learning object will also determine the capability of the learning object to be reused. But there is no standard that limit how big the learning object should be, so that the learning object can be or cannot be reused. The complexity take a role to the maintenance stage of the learning object [20]. Based on the reusability research, the object that reusable must not be hard to maintain because of its complexity. For this variable, the learning object complexity will be assumed as unity because of the classes' inheritance that almost hard to be mapped on the learning object area [21]. So, the number of method within the class, or it called features number will be the data for this variable measurement. All value can be seen in table 4.

Table 4. Learning object feature value

LO	Features Number	Value of Size	Value of Complexity
Courses A1	3	3	0.30
Courses A2	3	3	0.50
Courses A3	3	3	0.70
Courses B	3	3	0.90
Courses C	3	3	0.10
Quiz A	6	6	0.10
Quiz B	6	6	0.30
Quiz C	6	6	0.70
Flipbook A1	11	11	0.50
Flipbook A2	11	11	0.90
Flipbook A3	11	11	0.30
Flipbook B	11	11	0.10
Flipbook C	11	11	0.70
Video A1	7	7	0.30
Video A2	7	7	0.10
Video A3	7	7	0.50
Video B	7	7	0.90
Video C	7	7	0.50

Size refers to the number of elements or features in a learning object. The larger the Size, the more elements need to be managed in the e-learning system, which can affect the way content is presented and managed [22]. Size varies from 3 to 11 features, which indicates there are learning objects with different numbers of features. Complexity is directly related to how the elements of the learning object are interconnected, and the higher the value, the more complex the relationship between the features [23]. At sizes such as 7 or Size, the Complexity value still varies depending on the number of relationships that exist between the elements.

Complexity is affected by H_a, which indicates that even if the size (number of features) increases, the complexity level can also remain the same or change according to the percentage of relationships between features. Size and Complexity are important metrics in designing and managing e-learning systems. Larger size can bring challenges in terms of content management and maintenance, while high complexity indicates the need to be more careful in designing interactions between elements, so as not to confuse or over-complicate the learning process and understanding how size and complexity interact helps e-learning system developers create a more structured and effective learning experience [24].

3.5. Educational Portability

Based on Government Regulation of Indonesian Republic No. 17 of 2010 about management and delivery of education, declare that Indonesian formal education divided into three levels, primary, middle and higher education [25]. The description can be seen on table 5.

Table 5. Formal education level

Education Level	Education Type
Primary	Primary School
	Junior High School
Middle	High School
Higher	Diploma
	Bachelor
	Master
	Specialist / Profession
	Doctoral

Primary education in Indonesia covers education for children aged 6 to 12 years old and includes Primary School (SD) and Madrasah Ibtidaiyah (MI). At this level, learning objects are usually simple materials, with the use of visual aids or multimedia designed to facilitate the understanding of basic concepts. Learning objects for the primary level are usually more limited as the content must be adapted to the cognitive development level of younger students. Learning objects should be easily adapted to the curriculum set by the Indonesian Ministry of Education and Culture (Kemdikbud).

Secondary education in Indonesia includes junior high school (SMP) and senior high school (SMA). At this level, students begin to learn more complex material, and the learning objects used tend to be more in-depth and diverse, including text, diagrams, videos and interactive simulations. The learning objects need to be compatible with the national curriculum and adaptable for different models of secondary education, as although there are national curriculum guidelines, certain schools may have a different focus or approach (e.g. faith-based schools, or schools with special programs such as STEM).

Higher education in Indonesia includes education in colleges, such as universities, institutes and high schools, which offer bachelor's, master's and doctoral programs. At this level, learning objects tend to be more detailed and focus on practical skills as well as advanced theories. learning objects at the higher education level are more flexible as the materials used are more general and can be adapted for various disciplines [26]. The main challenges at this level are the differences in quality standards, academic focus, and the use of different software or learning platforms in each institution.

Reusability metric in educational portability must be adjusted to the characteristics and needs of each level of education. In primary education, learning objects are simpler and focus on reuse with little modification. In secondary education, objects are more flexible and modular to be used in various contexts, while in higher education, learning objects should meet high interoperability standards and support independent learning [27]. To achieve optimal educational portability across all levels of education, learning objects need to be designed by considering curriculum compatibility, adaptability to various technologies, and low adaptation costs.

3.6. Technical Portability

For this variable measurement, the data will be obtain from Google analytic that linked to the e learning website [28]. The data that will be taken is the number of operation systems, number of devices and number of application/browser that user used to access the learning object. Table 6 will be listed the summary of the platform, devices and browser that user used.

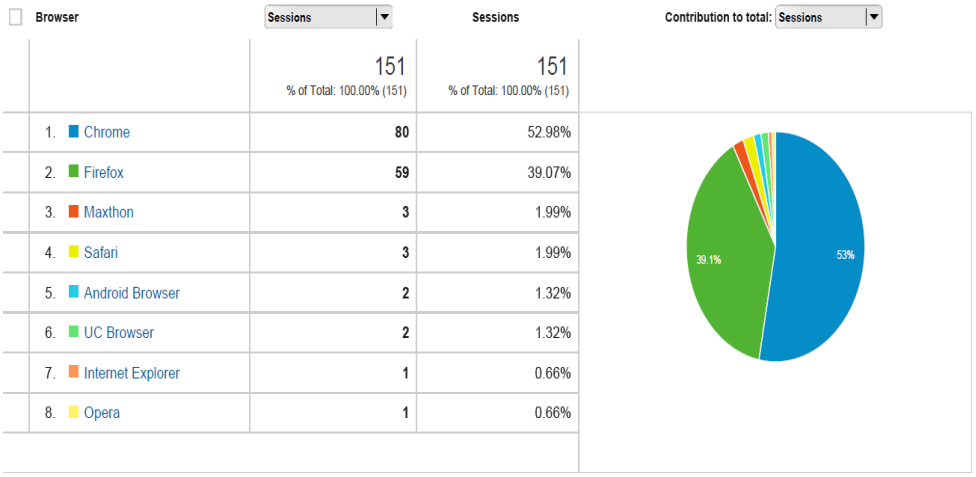

Figure 5. Google analytics for bsn e-learning browser statistic

Table 6. Technical system interaction

Device	Operation System	Browser
Desktop	Windows	Chrome
Mobile	Linux	Firefox
	Android	Maxthon
	IOS	Safari
		Android Browser
		UC Browser
		Internet Explorer
		Opera

The e-Learning of Standardization and Conformity Assessment have 18 learning object that have been evaluated by the metric with various result. Table 7 shows the result for cohesion, coupling and size.

Table 7. Evaluated metric with various result

LO	Cohesion	Coupling	Size	Complexity
Courses A1	0.50	0.45	3	0.30
Courses A2	0.70	0.60	3	0.50
Courses A3	0.36	0.30	3	0.70
Courses B	0.86	0.75	3	0.90
Courses C	0.50	0.40	3	0.10
Quiz A	0.27	0.20	6	0.10
Quiz B	0.51	0.44	6	0.30
Quiz C	0.75	0.65	6	0.70
Flipbook A1	0.71	0.62	11	0.50
Flipbook A2	0.63	0.55	11	0.90
Flipbook A3	0.82	0.72	11	0.30
Flipbook B	0.57	0.48	11	0.10
Flipbook C	0.69	0.60	11	0.70

Video A1	0.72	0.63	7	0.30
Video A2	0.61	0.52	7	0.10
Video A3	0.74	0.65	7	0.50
Video B	0.65	0.55	7	0.90
Video C	0.70	1	7	0.50

The type of education shows that educational portability from educational level value is larger than half of the formal educational level set by the Government, which means the learning object is quite portable from the side of educational level [29]. The comparison is shown in table 8. From the data obtained from Google Analytics, the FSP metric will calculate the number of devices, platforms, and browsers used. Table 9 will list a summary of the platforms, devices, and browsers used.

Table 8. The comparison result for educational portability

Education Level	Formal Education Type	Education type (*Et*)
Primary	Primary School	-
	Junior High School	-
Middle	High School	-
Higher	Diploma	Diploma
	Bachelor	Bachelor
	Magister	Magister
	Specialist / Profession	Specialist / Profession
	Doctoral	Doctoral
	∑Hs = 8	***∑Hs = 5***

Table 9. Technical system interaction

Device	**Operation System**	**Browser**
Desktop	Windows	Chrome
Mobile	Linux	Firefox
	Android	Maxthon
	IOS	Safari
		Android Browser
		UC Browser
		Internet Explorer
		Opera
∑Hs = 2	*∑Ps = 4*	*∑As = 8*

FSP = ∑ *System Interaction of One Functional*
FSP = $\sum H_s + \sum P_s + \sum A_s$
FSP = 2+4+8
FSP = 14

Table 9, showed that the learning objects can be accessed by the desktop or mobile devices. If the console device is excluded, it means that the learning object is portable in any devices [30]. For the operation systems, the result shows that the learning objects also can be accessed by any common platform that popularly used by the users, it is also indicates that the learning objects are platform free. From more than 5 popular browsers that been used, 8 browsers that user used to access the learning object shows the high result for software portability [31]. The FSP value showed that the result of the system interaction between the devices, operation systems and browser are good and take a high value, and it indicate that the learning objects is portable across the different devices, platforms and browsers.

4. CONCLUSION

This research has demonstrated quantitative measurements for learning object reuse with collaborative methods applied from software engineering development measurements and object-oriented metrics. From the five reuse variables for learning objects, it shows that from these variables, learning objects can be reused. The

cohesion values, ranged from 0.27 to 0.86, indicating variations in the degree of relatedness of the elements in the learning object. Most of the cohesion values are in the medium to high range. This suggests that the elements within the learning objects are reasonably well connected, although there are some low values. Coupling values range from 0.20 to 0.75. Most of the coupling values are in the medium to low range, indicating that the system design tends to be relatively independent, which suggests a modular and reusable design. The results for the size variable also show that the learning objects are in the medium to good size of reusable learning objects.

Some learning objects have a good size such as Course and some others such as Flipbook are also considered to have a good size because it also has many features in it. The portability variable also shows good results. In terms of education portability, the learning object has a score of 5 which is in the medium rank, since the e-learning system is developed for higher education level. However, for the learning object itself, it should be reusable for all eight levels of formal education in order to be considered as a good reusable learning object. From technical portability, it yields a score of 8 indicating the learning object is platform-free and portable on any device.

For future research, educational portability from primary to higher education needs to be evaluated and measured to ensure that learning objects can be reused across different educational disciplines, so peer review and expert review need to be conducted. The scope of study for learning object reuse also needs to be done, technical portability needs to be evaluated more deeply to show in what kind of environment the learning object has a very good impact, because reuse will be closely related to how users access the website again to finally reuse the learning object. Finally, the application of other object-oriented metrics such as xAPI and their results can be compared with the results of this study.

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