An Asynchronous Serial Communication Learning Media: Usability Evaluation

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Abstract. The availability of a good acceptable learning media is a vital part of the learning process. This paper presents a usability evaluation of the asynchronous serial communication module, which can exhibit the level of acceptance of Data Communication's students. The survey was performed based on ten simple statements of the System Usability Scale (SUS) questionnaire. The research's findings have been analyzed in three different approaches, i.e., visual "five-pointed star" shape assessment, Bangor et al. model verification, and curved grading scale justification. The analysis showed that the serial communication module is in the acceptable category.

1. Introduction
The learning media is one essential component in the learning process to enhance the student's outcome and performance. In the Data Communication Practice course, one important topic is discussing the serial communication. Different from parallel communication, which is relatively easy to understand, the serial communication is rather challenging to figure out. This situation is getting worse with the absence of the appropriate serial module. The old-version serial module has some limitations [1]; there is no information concerning serial data bits in detail. It cannot show the typical data in serial communication such as the start bit, data bits, and stop bit. The previous study proposed the new serial communication module equipped with graphical serial data information [1].

Although, it was reported that the serial module could functionally perform as designed [1]. However, it is important to evaluate the module in terms of the usability collected from the user's perspective. Usability evaluation is one of the methods allowing the user to evaluate the usability of the products through any approaches, e.g., field observations [2], interviews [3], focus groups [4], and questionnaire [5]. The questionnaire method is widely used to assess usability because of its simplicity, economic, and reliable. Therefore, the primary goal of this article is to explore the usability evaluation of the asynchronous serial communication module through the most widely used SUS (System Usability Scale) instrument.
2. Asynchronous Serial Communication Learning Media

The serial module used in this study is the asynchronous serial communication learning media designed and developed in the previous study [1]. This serial module proposes a visualization of a serial bit data in order to facilitate the students to comprehend the serial communication easily. This module should be connected to the computer, either a desktop-based or notebook through a USB port that complies with the serial data characteristics.

Basically, this serial module consists of hardware and software. The hardware comprises of one graphic LCD and two sub-circuits, i.e., the main controller circuit and the serial interface circuit (see Figure 1). The LCD functions for displaying the serial data transferred from/to serial module. Meanwhile, the serial interface circuit provides the interface port to establish communication with the computer. The main process to interpret the non-visual serial data into the animated graphic is managed by the main controller circuit.

![Figure 1. The serial communication hardware module](image1)

Concerning the software, two different programs should be installed into one in computer and the other in the serial module. The program attached in the serial module creates based on the Code Vision AVR programming. Meanwhile, the program installed on the computer develops through the Delphi IDE (Integrated Development Environment). Figure 2 shows the GUI (Graphical User Interface) of the computer-side software.

![Figure 2. The serial communication software GUI](image2)
In terms of the hardware and software test, the thorough examination was conducted in the context of the functional-based test in order to assess the performance of the serial module. Four aspects of basic functions, receiving data, sending data, and visualizing data were tested carefully. The test results were reported that the serial module could perform as good as expected [1].

3. Usability Evaluation
The International Standards Organization (ISO) 9241 defined usability as the degree to which a specified product can be used by specified users to accomplish specified goals with considering effectiveness, efficiency, and satisfaction in a specified context of use [6]. Although there are no specific guidelines on how to overcome the measurement of the three aspects of effectiveness, efficiency, and satisfaction, a large number of usability tests have been studied and developed by practitioners and researchers. There are numerous well-known questionnaires available for evaluating the usability of the technological-based products based upon the subjective user assessment, e.g., the Questionnaire for User Interaction and Satisfaction (QUIS) [7], the Software Usability Measurement Inventory (SUMI) [8], the After-Scenario Questionnaire (ASQ) [9], the Computer System Usability Questionnaire (CSUQ) [9], the Post-Study System Usability Questionnaire (PSSUQ) [9], the questionnaire System Usability Scale (SUS) [10], the Website Analysis and Measurement Inventory (WAMMI) [11], and the USE questionnaire [12].

From those mentioned questionnaires, the one which offers many advantages in terms of simple, reliable, and low-cost assessment is the SUS. First, the SUS is constructed in a "quick and dirty" method [10]. This method made in order to meet the demands of evaluating usability in the industrial context that needed a quick and simple, but also reliable enough to assess the products. The SUS comprises only ten statements with a five-point possible response spanning from strongly disagree to strongly agree. With the very short and simple statements, it doesn't need much time and effort for respondents to complete the surveys.

Secondly, the SUS is technological agnostic [13] that is possible to be used to evaluate a wide variety of products. Some of the studies using SUS are websites [14], Learning Management Systems (LMSs) [15,16], adaptive e-learning [17,18], computer hardware [19], multimodal systems [20], interactive voice response systems [21], voting systems [22,23], mobile applications [24,25], mobile/PDA devices [26,27], safety signs [28], and medical systems [29].

Thirdly, the SUS is available free and has a public domain license. The public domain license means that the one who wants to use this instrument should maintain the attribution to the original developer. Fourthly, the SUS is proved a robust and valid tool for assessing the usability of products [16,30–33], even for a small number of respondents [34]. The detail about the SUS validity and reliability will be explained in the next section.

4. Research Design
In this section, the research method used in the study is explained. There are some points that importantly considered for discussing in order to provide a good understanding of this research. First of all, describing the psychometric instrument used to collect the user's perspective towards the serial module. Then, defining the participants involved in this work. Finally, the procedure conducted in this study is also described in detail.

4.1. Instrumentation
The instrument used in this study is derived from the SUS questionnaire [10]. Originally, the SUS questionnaire was written in the English version. Since the respondents in this study are the students from Indonesia, thus the questionnaire needs to be translated into the Indonesian language. The back-and-forth translation method was chosen to address this process. This translation method started by converting the original version of the questionnaire into the Indonesian version. Then, the Indonesian version was re-translated or back-translated to the original language. The back-and-forth translation was performed as literally as possible in order to obtain the exact meaning of the translation in the target
language. Certain aspects of clarity and readability were also considered in the translation process. Few modifications had been made by replacing the word 'system' with the word 'serial module' throughout the questionnaire. This replacement was performed in order to suit the context of this study as implemented by Bangor et al. [31]. With consideration of the precise meaning, the final version of the instrument was compiled in bi-language; the Indonesian and original text (see Appendix A).

The SUS comprises of 10 questions with a Likert scale form. A 5-point Likert scale is made to indicate the degree of agreement or disagreement of each item. Scale 1 states the strong disagreement (strongly disagree) to the intended statement, and scale 5 represents the strong agreement (strongly agree). It should be taken into consideration when providing the SUS to the respondents that there is a difference wording format for odd and even statements. The odd statements (1, 3, 5, 7, and 9) are associated with positive wording questions while the even statements (2, 4, 6, 8, and 10) are rather constructed in negative wording format [16].

The calculation process of the SUS score starts by summing the score contributions from each item. For the odd-numbered items (1, 3, 5, 7, and 9), the score contribution is getting by subtracting 1 from the scale position. For the even-numbered items (2, 4, 6, 8, and 10), the contribution is 5 minus the scale position. The score contribution for each item ranges from 0 to 4 (with four being the most positive response). After that, sum the score contributions for all items. Then multiply the summed score by 2.5 to get the total score. The SUS scores were ranged in between 0 to 100 [10].

4.2. Validity and Reliability of the SUS
Validity refers to how well an instrument can measure what it is intended to measure. Meanwhile, reliability refers to how consistent the instrument when it used to measure repeatedly. Concerning the validity and reliability of the SUS, many studies indicate that SUS is a robust and valid tool for usability evaluation.

Kirakowsky in 1994 reported that the SUS has a reliability of 0.85 [30]. It is categorized in an acceptable range of reliability. In 2004, Tullis & Stetson used five different tools, including QUIS, SUS, CSUQ, and two others to measure the usability of the website and found that the SUS was the most reliable tool even with a small sample, as low as 12 participants [34]. Additionally, extensive research managed by Bangor et al. (2008) involving more than 2300 surveys from more than 200 studies has demonstrated that the Cronbach's alpha was 0.91 [31]. This finding showed highly acceptable criteria for reliability. In 2009, Bangor et al. continued their research by adding adjective rating scale to nearly 1000 SUS surveys and found that a significant correlation (r=0.822) [32]. This finding strengthened the validity of the SUS questionnaire. Orfanou et al., in 2015, conducted the usability evaluation of two LMSs (eClass and Moodle) involving 769 students [16]. Analysis of the results indicated that the SUS was a considerably valid and reliable tool for assessment. Recent research conducted by Sauro & Lewis in 2016 has also confirmed that the SUS has excellent reliability and validity [33].

4.3. Participants
There were 43 second-year students of the Electrical Engineering Education Department, Yogyakarta State University, participating in this study. The research was conducted in one of the particular class meetings in the odd semester of the academic year 2018/2019. Among the respondents, 33 were male (76.74%) while 10 were female (23.26%).

4.4. Procedure
The typical characteristic of the Data Communication Practice course is the existence of computer as a tool to establish the data communication. This situation may lead to organize the course in the computer laboratory conveniently. Therefore, the usability evaluation study was conducted in the computer laboratory of the Electrical Engineering Education Department, Yogyakarta State University. Since the course has two credits, thus the total hour for this study is roughly four meeting hours.

In the first session, the explanation of the main objectives of the study, the serial module including its features, and the operating instructions were briefly given to the students. Then, a simple example
was demonstrated to the participants. In this period, the question and answer session was open for discussion. The next session was distributing the serial module to the students. It was followed by asking the students to use the module for the serial communication practice. The experiment program was following the instructional operating procedure written in the manual sheet. The students were allowed to try different functions offered by the serial module. The problems and shortcomings emerged along with the practice may be asked to the instructor. Around 15 minutes prior to the end of the meeting, the paper-based SUS questionnaires were distributed to the students. A short instruction to fill out the questionnaire was explained as clearly as possible. Then, the session was closed by collecting the fulfilled questionnaire.

5. Research Result and Discussion

To get the research results, the first process is preparing the data sets. From the collected questionnaires, the raw data were pre-processed by coding and tabulating to a data set. The final data sets as can be seen in Table 1 comprises of the single score for each individual statements, including the total average score. The “RAW Score” column displays the original mean scores. These scores are associated with positive and negative tone statements to distinguish the odd and even items. Meanwhile, the “SUS Score” column exhibits the mean scores from the standard calculation of SUS ranges in 0-4 and 0-100 format. These scores in principle try to adjust the scores of the even statements (2, 4, 6, 8, and 10) into the positive responses.

Although, the principal value of SUS is providing the single total score, however, it is still necessary to look into detail the individual score for each statement [31]. To address this, Caglarca suggested taking into account the evaluation by verifying the shape of a "five-pointed star" [35]. For doing that, the RAW scores from Table 1 have been transformed into the radar chart, as shown in Figure 3, Caglarca also concluded that the more the "five-pointed star" looks like, the more positive result of the usability will get [35]. As can be seen in the chart, although it tends to be subjective assessment, however, it indicates that the "five-pointed star" shape is almost in perfect form.

| Statements                                                                 | RAW Score | SUS Score |
|---------------------------------------------------------------------------|-----------|-----------|
| 1. I think that I would like to use this serial module frequently.        | 3.44      | 2.44      | 61.05    |
| 2. I found the serial module unnecessarily complex.                       | 2.60      | 2.40      | 59.88    |
| 3. I thought the serial module was easy to use.                           | 4.47      | 3.47      | 86.63    |
| 4. I think that I would need the support of a technical person to be able to use this serial module. | 2.72 | 2.28 | 56.98 |
| 5. I found the various functions in this serial module were well integrated. | 3.93 | 2.93 | 73.26 |
| 6. I thought there was too much inconsistency in this serial module.      | 2.16      | 2.84      | 70.93    |
| 7. I would imagine that most people would learn to use this serial module very quickly. | 4.14 | 3.14 | 78.49 |
| 8. I found the serial module very cumbersome to use.                      | 1.51      | 3.49      | 87.21    |
| 9. I felt very confident using the serial module.                         | 3.84      | 2.84      | 70.93    |
| 10. I needed to learn a lot of things before I could get going with this serial module. | 2.72 | 2.28 | 56.98 |

Table 1. Responses to individual statements of the SUS
As there is no standard to interpret whether the particular score represents the acceptance of users for specific products or not, Bangor et al. attempted to provide a grading scheme for the SUS score interpretation [31]. They determined the SUS score into the traditional school grading scale (from 0 to 100 with 100 is the most positive score) [32]. Furthermore, based upon the average mean score and considering the traditional passing score, they proposed score 70 as an acceptable threshold. The detailed SUS score interpretation, including the acceptability ranges, grade scale, and adjective rating, can be seen in Figure 4.

From Table 1, it is interesting to see that the minimum score is 56.98 (statement 4) and the maximum score achieved by statement 8 (reaches 87.21). Concerning the acceptability ranges, score 56.98 is categorized as marginal low, and score 87.21 is in the acceptable range. Looking at the average rating (70.23) achieved, it is slightly higher than the acceptable limit set by Bangor et al. It is also indicated that the score 70.23 is in grade “C” and somewhat below the “Good” of adjective rating.

Another approach for determining the SUS score was conducted by Sauro & Lewis [33]. They develop the Curved Grading Scale (CGS) to interpret the SUS score into the grade and percentile rank (%). Based on the data from over 400 studies and more than 5000 individual SUS responses, they found
that the overall mean score of the SUS is 68 and decided to use it as an acceptable limit [33]. This average score is a little bit below the score limit (70) suggested by Bangor et al.

As can be seen in Figure 5, the SUS score achieved in this study (70.23) is above the acceptable criteria suggested. The score of 70.23 also represents a percentile rank of around 56%. This means that score 70.23 has higher perceived usability than 56% of all products tested in the database of [36]. It also confirms that score 70.23 is classified as a grade C.

![Figure 5. SUS percentile rank](image)

6. Conclusion

In the Data Communication Practice course, one essential part is the availability of the serial communication module to support the students for easily grasping the intended knowledge. It is also important to assure that the learning media may be usable for the students. In this paper, empirical usability evaluation of the serial module has performed through the popular, proved valid, and reliable SUS questionnaire.

The average SUS score achieved in this survey reaches as high as 70.23 (out of 100). Though, there is no standard guidance to decide whether the SUS scores reported in this study classified as acceptable. Hence, the findings are discussed with respect to three different acceptance criteria. First, taking into account the visual judgment of the "five-pointed star" shape suggested by Caglarca [35], it was found that the star shape associated with the SUS score of this study indicated a relatively good contour. It means that there is a positive acceptance from the students for the serial module.

Second, based upon the acceptance limit suggested by Bangor et al. [31] the SUS score in this study was classified as acceptable and indicated as grade “C” and slightly below the “Good” of adjective rating. Third, according to the curved grading scale of Sauro & Lewis [33], the finding in this study could exceed the acceptance threshold. It also confirms that the SUS score of this study has the same grade as Bangor et al. have.

All in all, it can be concluded that the existence of the serial communication module might be accepted by the students and may lead to the improvement of the learning outcome particularly in the topic of serial communication. However, this study only digs the usability evaluation from the subjective student's perception. Therefore, a further investigation from other sorts of perspective for instance interview or expert-based evaluation may bring to the comprehensive results.
7. Appendix A

Angket Penilaian Modul Serial oleh Pengguna

Questionnaire of Serial Module Evaluation by User (Students)

1. Saya pikir saya akan sering menggunakan modul serial ini.
   I think that I would like to use this serial module frequently.
   [strongly disagree, 1 2 3 4 5 strongly agree]

2. Saya merasa modul serial ini tidak perlu dibuat kompleks.
   I found the serial module unnecessarily complex.
   [1 2 3 4 5]

3. Saya pikir modul serial ini mudah untuk digunakan.
   I thought the serial module was easy to use.
   [1 2 3 4 5]

4. Saya pikir saya akan membutuhkan bantuan dari teknisi untuk dapat menggunakan modul serial ini.
   I think that I would need the support of a technical person to be able to use this serial module.
   [1 2 3 4 5]

5. Saya merasa berbagai fungsi dalam modul serial ini terintegrasi dengan baik.
   I found the various functions in this serial module were well integrated.
   [1 2 3 4 5]

6. Saya pikir ada terlalu banyak ketidakkonsistensan dalam modul serial ini.
   I thought there was too much inconsistency in this serial module.
   [1 2 3 4 5]

7. Saya bayangkan kalau banyak pengguna yang akan belajar menggunakan modul serial ini dengan sangat cepat.
   I would imagine that most people would learn to use this serial module very quickly.
   [1 2 3 4 5]

8. Saya merasa modul serial ini sangat sulit untuk digunakan.
   I found the serial module very cumbersome to use.
   [1 2 3 4 5]

9. Saya merasa sangat percaya diri menggunakan modul serial ini.
   I felt very confident using the serial module.
   [1 2 3 4 5]
9

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