Validity and Practicality of Student Activity Sheets (LAM) of Real Number Sequences with the Aid of Geogebra Based on the APOS Model

Hanifah Hanifah(✉) and Istikomar Istikomar

Mathematics Education Study Program, University of Bengkulu, Bengkulu, Indonesia
hanifahmat@unib.ac.id

Abstract. This study aims to determine the validity and practicality of student activity sheets (LAM) assisted by geogebra based on the APOS model. The research was carried out at the program studi pascasarjana pendidikan matematika Universitas Bengkulu. This type of research is development research that uses the Plomp model. The data obtained from the results of the validation of the experts, the practicality of the individual test, the small group test and the large group test using the validity and practicality test sheet instrument in the form of a five-scale questionnaire. The average score obtained from expert validation is 0.95 based on the Aiken index, including the valid category. In the analysis of practicality, obtained by individual practitioners 4.8; small group practitioners 4.5 and large group practitioners 4.6. The average value obtained is more than 4.2, which means that the student activity sheet has a very practical category to be used in supporting the teaching and learning process.

Keywords: APOS Model · LAM · Geogebra · Student

1 Introduction

The Real Analysis course is a compulsory subject offered at the program study magister pendidikan matematika Universitas Bengkulu with a weight of 3 credits. The material provided consists of: Section 1. Introduction consisting of: Set Algebra, Functions, and Mathematical Induction; Section 2 Real Numbers; Section 3 Real Number Sequences; Section 4 Function Limits; and Section 5 Continuous Functions [1, 2]. The real analysis course is a very difficult level. Students must master supporting materials such as Calculus, Sets and Mathematical Logic. The abilities that students must achieve after studying this course are that students can analyze problems using exciting definitions/theorems/effects/lemmas and solve problems with mathematical logic (logical reasoning skills).

Based on the results of a poll on S2 Mathematics Education students who took part in a comprehensive study in February 2021 conducted by 17 people, regarding the implementation of the previous Real Analysis learning, the following information

M. L. Firdaus and A. Defianti (Eds.): MASEIS 2021, ASSEHR 718, pp. 97–106, 2023.
https://doi.org/10.2991/978-2-38476-012-1_14

was obtained: 82.35% of students said that: 1) The material studied was Section 2, Section 3 and Section 4. The main source books are the Book of Real Analysis by Bartle; 2) The material is distributed to students. Each student gets one subject. Before the Pandemic, the presenters presented in front of the class, when they had to Work From Home (WFH), students presented via zoom; 3) Students generally do not understand the material presented by their friends. When lectures at Zoom, most of the analytical materials are difficult to reach due to limited space, tools and limited ability of presenters. The lecturer did not have time to give feedback on zoom because of the limited zoom time. The result of material analysis becomes a subject that is difficult for all students to understand.

Wahyuni [3] states that a number of research results show that problems related to students' mathematical proof abilities are caused by several things, namely: (1) weak mastery of prerequisite material such as sets, number systems, properties of binary operations, relations and functions, limits and function derivative; 2) lack of exercise intensity in mathematical proof; 3) the number of definitions and theorems that must be mastered so that students are confused in determining which definition or theorem should be used to prove a problem. Lectures given online via Zoom also make it difficult for students to understand the lecture material.

This is also supported by the findings of Perbowo & Pradipta [4], namely 83% of students are unable to write proof of theorems at all and only 6% of students can provide complete and correct evidence. In addition, he also obtained data that there were no students who were able to provide proof of the contrapositive form at all, while only 6% of students were able to provide a form of proof of the contradiction.

To overcome the above, the instructor is there not only to present the materials that the student needs to discuss, but also to teach as needed. One way to help students understand the material is to ask them to draw a diagram from the sample questions explained, either manually or using the Geogebra assisted zoom. Assigning students to complete homework is sometimes accompanied by sharing learning videos uploaded from the internet.

The sequence of real numbers is a function on the set of natural numbers with the result area contained in R [1]. So if $\boldsymbol{x}$: N $\rightarrow$ R is a sequence, it can be written as $\boldsymbol{x}$ in n with $\boldsymbol{x_n}$ or $(\boldsymbol{x_n}: \boldsymbol{n} \in \boldsymbol{N})$. If the limit of the sequence is $(\boldsymbol{x_n})$, then $(\boldsymbol{x_n})$ we say that convergent to x or $\boldsymbol{lim}(\boldsymbol{x_n}) = \boldsymbol{xor} \lim_{n\to\infty} \boldsymbol{x_n} = \boldsymbol{x}$ or $\boldsymbol{x_n} \rightarrow \boldsymbol{x}$. The following is an example of the convergent of a sequence that can be analyzed based on a graph first to make it easier to find out (Fig. 1).

From the graph, it can be seen that the value of $\boldsymbol{x_n}$ is always aproach to 2, but never equal to 2, so we get $\mathbf{lim}\frac{2n}{n+1} = 2$. So $\boldsymbol{x_n}$ convergent to 2 and $\mathbf{lim}\frac{2n}{n+1} = 2$. . In making the graph is made with the help of the geogebra application. Geogebra is a non-profit free software for use by Indonesian math educators (teachers and teachers) [5]. This software can be used as one of the recommended media for learning math, as a practical term for demonstrating or visualizing math concepts, and as a tool for creating math concepts. Provides a variety of menus [6]. So that in addition to learning the sequence of real numbers, students get new knowledge by knowing Geogebra software and being able to use the application in drawing lines, graphs and line equations [7].

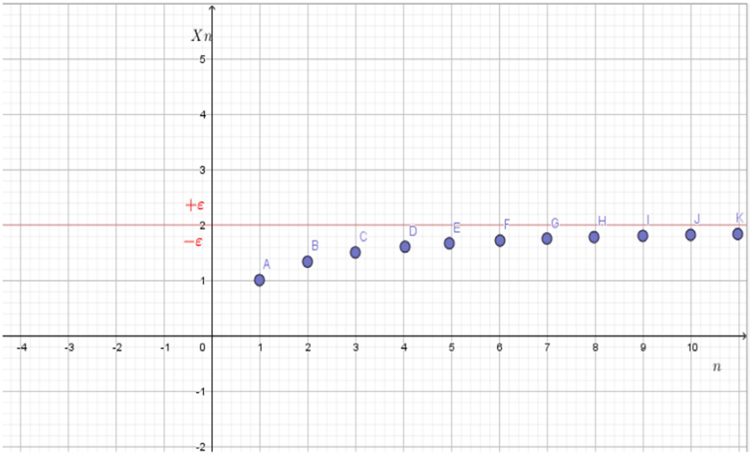


Fig. 1. Example of a graph of a real number sequence $x_n = \frac{2n}{n+1}$

Comments from X1 students about the implementation of real analysis learning. "I enjoy learning real analysis through individual presentations and with the help of geogebra. Because when we were undergraduate, we didn't use geogebra when we studied this material. In my opinion, the use of geogebra when studying is continued and developed so that learning is more interesting and remains in the context to be studied. The influence of geogebra to help understanding is when I have difficulty understanding the description of real theorems, the image on geogebra helps me understand the sentences that I have analyzed through the analysis, so that the image strengthens the theorems studied. In addition, if I don't understand how to prove a problem based on theorems, I can take steps through geogebra first, see then I describe a problem based on analysis if the geogebra proves correct". Student X2 comments. "initiative the lecturer sent a youtube link related to learning, gave the correct answer to a friend's assignment in WhatsApp Group, directed to the Geogebra application. It was very easy for me to answer questions through graphs." All students agreed that geogebra was very helpful for students in understanding the material.

APOS theory is a constructivist theory of how to learn the concept of mathematics. The theory is essentially based on hypotheses about the nature of mathematical knowledge and how that knowledge develops. The process of forming new knowledge (especially mathematics) is believed to be the result of a series of processes introduced by Dubinsky as Action Process Object Schema (APOS). Objects stored in memory as knowledge are processed when an action occurs in response to a particular stimulus [8].

In line with the curriculum changes in 2013 that were oriented towards student-centered learning, the APOS Theory Based Calculus Learning Model (MPK-APOS) was developed [9]. MPK-APOS can actually be used in the Transformation Geometry course. As a result, the letter K, which stands for Calculus, is not suitable for use in geometry, so MPK-APOS was developed into the APOS Model [10]. APOS model implementation supported by APOS model-based worksheets. The 2015 Worksheet Design when applied did not reflect the syntax of the APOS Model, so an improvement was made to the worksheet design that followed the syntax of the APOS Model and was poured into a book with the title Computer Aided APOS Model [11].

In addition, prior to the Covid-19 pandemic, researchers were accustomed to applying the APOS model in the FKIPUNIB Integral Calculus course, an undergraduate course in mathematics. The application of the APOS model is supported by the APOS model-based integral calculus worksheet. Based on this, it is deemed necessary to develop a Student Activity Sheet (LAM) of Geogebra Assisted Real Number Sequences Based on the APOS Model.

2 Method

This type of research aims to develop student activity sheets based on the APOS model using Geogebra and learning videos. The development model for this study follows the general development model by Plomp [12]. It consists of three stages: preliminary research, development or prototyping stage, and evaluation stage. At the preliminary research stage, the aim was to analyze theoretically how the geogebra-assisted student activity sheet based on the APOS model could be implemented in students of the Program studi Magister pendidikan matematika FKIP UNIB. At this stage, curriculum and material analysis is also carried out to identify instructions that can be used as a reference for LAM. The development or prototyping phase is the activity of designing worksheets that support the implementation of the APOS model.

The purpose of this study was to determine the validity and practicality of student activity sheets with the support of educational and geogebra videos based on APOS Models. The instrument used to collect data is the instrument of validity and practicality of LAM in the form of a Likert scale. The research subjects were 2 validators who were taken from 2 fields of study, namely 1 person for pure mathematics and 1 person in mathematics education who mastered real analysis and computer learning. At the product trial stage, field trials were conducted in the use of the product by students and lecturers, which consisted of individual trials by 1 student, 1 alumni and 1 teacher, small group trials by 3 students in 1 group, and large group trials by 12 students postgraduate mathematics education at the UNIB. Meanwhile, in the Revision and Analysis Phase, it is carried out when the user provides criticism and suggestions for product improvement.

In the product in the form of Student Activity Sheets (LAM), the aspects that will be validated by experts are aspects of the suitability of content and material, LAM layout settings, compatibility with linguistic components, compatibility of presentation components, benefits of using LAM, compatibility with APOS and Geogebra models. Meanwhile, during the practicality test by students, the aspects that will be validated are aspects of instructions, aspects of content, aspects of language.

The content validity estimate used in this study uses the item validity index proposed by Aiken in the following formula:

$$\boldsymbol{V} = \frac{\sum \boldsymbol{s}}{\boldsymbol{n}(\boldsymbol{c}-1)},\ \textit{\textbf{with}}\ \boldsymbol{s} = \boldsymbol{r} - \boldsymbol{I}_0 \quad (1)$$

Table 1. Criteria for Validity of LAM.

Index of Aiken	Category
>0,5	Valid
≤0,5	Invalid

Table 2. Criteria for practical learning tools.

Score Interval	Category
$X > 4, 20$	Very Practical
$3, 40 < X \leq 4, 20$	Practical
$2, 60 < X \leq 3, 40$	Enough
$1, 80 < X \leq 2, 60$	Less Practical
$X \leq 1, 80$	Not Practical

Information:

$\boldsymbol{V}$ = validity index
$\boldsymbol{s}$ = score assigned by each evaluator minus the lowest score
$\boldsymbol{r}$ = Rating of the selected rating category
$\boldsymbol{I}_0$ = lowest score in rating category
$\boldsymbol{c}$ = number of categories the evaluator can select
$\boldsymbol{n}$ = number of evaluators [13]

The criteria for the validity of the LAM developed are shown in Table 1 [14].

The data from practicality trials which have been received are transformed into qualitative records with a scale of five. Then the category is determined and the results of the conversion of each component developed are presented in the Table 2 [14].

3 Result and Discussion

At the stage of developing and making prototypes, the design and validation process was carried out by several experts and practicality tests were tested on students. The following describes the results of the design, validation and Practicality Test of the developed LAM.

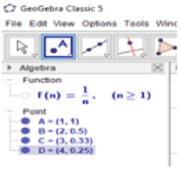
The resulting Student Activity Sheet (LAM) is a Geogebra-assisted LAM based on the APOS model which is designed using the steps in the APOS model. The following is the syntax used in the application of APOS Theory for learning in schools which is modified from the APOS Theory syntax according to Hanifah [6].

a. Orientation Phase. Activities direct students to be ready to accept learning with the latest topics. Read the summary of the material on the LAM and continue watching the learning videos on the LAM.

a) Input langsung Rumus pola ke n nya seperti berikut ini.

Lalu tekan "enter" pada keyboard.

b) Karena n hanya untuk bilangan asli, sehingga grafiknya hanya berupa titik-titik. Gunakan tools "Point", kemudian letakkan kursor pada titik-titik yang berhubungan dengan n bilangan asli. Serta kosongkan bulatan pada bagian rumus fungsi. "dengan cara di klik". Sehingga pada sebelah kiri akan tampak seperti berikut ini.



c) Grafik barisan $x_n = \frac{1}{n}, n \in \mathbb{N}$ sudah terbentuk.

Fig. 2. Example of the contents of the practicum stages in LAM

Pada grafik B apakah nilai limitnya dapat ditentukan ?......

jika dapat berapakah nilainya? . . .

Jadi barisan $x_n = \frac{\sqrt{n}}{n^2}$ konvergen ke. . . .sehingga $\lim_{n\to\infty} \frac{\sqrt{n}}{n^2} = \ldots$

Ambil Sembarang $\varepsilon > 0$, Berarti ......> 0.

Menurut sifat archimedes,

terdapat $n_0 \in \mathbb{N}$ sedemikian sehingga $n_0 > \frac{1}{\varepsilon}$. Sehingga $\frac{1}{n_0} < \ldots$

jadi untuk setiap $n \geq n_0$ *atau* .....$\leq \frac{1}{n_0}$ berlaku

Fig. 3. Example of the contents of the small group discussion stages in LAM

b. Practical Phase. The student phase carries out orders for a Geogebra application program for school geometry, where these commands are available on the Worksheet in the Practicum phase. The purpose of the practicum phase is to introduce students to a new situation or information (new concepts). The practicum phase was chosen because it has been explained previously that the characteristics of learning mathematics based on APOS theory are that knowledge is constructed using mental APOS (Action, Process, Object and Schema) (Fig. 2).

c. Small Group Discussion Phase. Phase students in small groups discuss or answer the questions that have been provided on the Worksheet for the Small Group Discussion phase. These questions will lead students to find the concepts they are studying.

d. Class Discussion Phase. An activity where the selected group of students presents their conclusions or presents the completion of one of the questions in the small group discussion phase or other questions in front of the class. The class discussion that was held after the group discussion was intended so that students who were able to solve the problems in the small group discussion phase could explain them in front of the class so

Table 3. Results of the Validation Questionnaire by the Experts.

Rated aspect	Average	Information
Conformity of Content and Material	0,99	Valid
LAM Layout Settings	0,88	Valid
Compatibility with Linguistic Components	0,93	Valid
Compatibility of Presentation Components	0,93	Valid
Benefits/Uses of LAM	1,00	Valid
Compatibility with APOS and Geogebra Models	0,98	Valid
Amount	5,70	
Average	0,95	

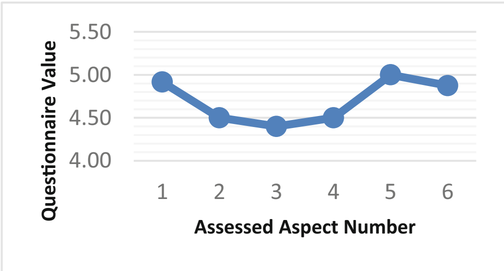


Fig. 4. Graph of the results of the validation questionnaire by experts

that their friends in the class had the same understanding. If students make a mistake, the educator can straighten it out by providing scaffolding.

e. Exercise Phase. The purpose of the Exercise phase is to strengthen students' understanding of a subject, which was discussed in the previous phase. Limited time in class, so the questions in the Practice can be used as homework. In completing homework, students are asked to study the real analysis book, so that the limited time and information in class can be completed by students from studying the real analysis book at home.

After designing a geogebra-assisted LAM based on the APOS model, the product in the form of a geogebra-assisted LAM based on the APOS model was validated by experts. The following are the results of LAM validation by experts, which can be seen in Table 3.

For greater details, the outcomes of the validation questionnaire may be visible with inside as shown in Fig. 4.

In the graph it can be seen that the results of the LAM validity test for each aspect are valid. For aspects of the suitability of content and materials, LAM layout settings, compatibility with linguistic components, suitability of presentation components, benefits/usability of LAM, conformity with APOS and geogebra models are appropriate and can be said to be valid by obtaining a validity value in the range of 0,88 to 1 with

Table 4. Results of the Practicality Questionnaire.

	Average Practicality			Information
	Individual	Small group	Big group	
Aspect Hint	4,8	4,3	4,4	Very Practical
Content Aspect	4,8	4,5	4,6	Very Practical
Language Aspect	4,9	4,7	4,8	Very Practical
Amount	14,4	13,5	13,8	
Average	4,8	4,5	4,6	

valid category. This means that from the component aspect, the designed LAM is valid according to experts.

After the Geogebra-assisted Student Activity Sheet (LAM) based on the APOS model was validated by experts, the product was tested for practicality of individuals, small groups and large groups. The results of the practicality questionnaire obtained, are seen in Table 4.

Based on the table, the results of the LAM practicality test questionnaire are: individual test = 4,80; according to small group 4,50; according to the large group of 4,60. The average practicality value of LAM by users is 4,63. If it is adjusted to the eligibility guidelines for the Student Activity Sheet (LAM), it is in a very practical qualification. So that the product is ready to be used in the actual field for learning activities. According to practitioners, activities at LAM are very practical to be used in learning, especially practicum activities that can increase students' understanding, creativity, and independence. The LAM which will be used in the real number sequence material has been directed with sentences that are easily understood by students and the graphing procedure in Geogebra has been described in detail in several ways so that students can choose the way they like to make the next graph. The suggestions from respondents were that it would be even better if the LAM contained other reading references so that students were not only fixated on LAM and learning in class.

Figure 3 shows the Geogebra command in action. When the geogebra command is executed, a graphic image will appear making it easier to introduce a convergent or divergent real number sequence before analytical proof is carried out. LAM users such as lecturers, teachers and senior students agree that the geogebra-assisted student activity sheet based on the APOS model is practical with an average practicality questionnaire score of 4.6.

Geogebra-assisted student activity sheets based on the APOS model received a positive response from most of the lecturers and students. A student activity sheet is said to be eligible if it has valid criteria, the validity of the student activity sheet is assessed by experts or professionals in their fields [15]. The use of Geogebra in learning is positively accepted by most educators. Previous studies have also found that many students are actively aware of Geogebra software and can improve their understanding of the concept of mathematics [16]. In addition, most students are very interested in learning how to use Geogebra software [17]. In addition, using Geogebra for learning is also effective in establishing interactions between teachers and students during the learning process [18]. Using Geogebra in mathematics can facilitate the teaching and learning process by providing easy-to-use, content-rich visualizations [19].

4 Conclusion

Based on the results of the research conducted, we can conclude that: the student activity sheet (LAM) assisted by geogebra based on the APOS model as a support for the teaching and learning process in real analysis courses is valid and practical.

Acknowledgments. The authors would like to thank the head of the PMIPA department and the Dean of the Faculty of Teacher Education for funding this research.

References

1. Bartlle, R.G., "Introductions to Real Analysis (2nd ed.)," New York: John Wiley & Sons, Inc. (2000).
2. Jafar, "Analisis Real I dan II Sebuah Terjemah dari Sebagian Buku Introductions to Real Analysis", Komunitas Studi Al Khwarizmi. Unaaha: Robert G. Bartle (2012).
3. Wahyuni, M., "Analisis Problematika Perkuliahan Analisis Real", Jurnal Pendidikan Matematika, vol. 1, no. 1, pp. 145-151 (2017).
4. Perbowo, K. and Pradipta, K. R., "Pemetaan Kemampuan Pembuktian Matematis Sebagai Prasyarat Mata Kuliah Analisis Real Mahasiswa Pendidikan Matematika", Jurnal Pendidikan Matematika, vol. 02, no. 1, p. 88 100 (2017).
5. Nisiyatussani, Ayuningtya, V., Fathurrohman, M., and Anriani, N., "Geogebra Applets Design and Development for Junior High School Students to Learn Quadrilateral Mathematics Concepts", Journal on Mathematics Education, vol. 9, pp. 27–40 (2018).
6. Tamam, B., and Dasari, D., "The Use of Geogebra Software in teaching Mathematics", Journal of Physics: Conference Series, vol. 1, pp. 1-6 (2020).
7. Telaumbauna, Y. N., "Analisis Pembelajaran dengan Menggunakan Software Geogebra dalam Pembelajaran Matematika", J-PiMat, vol. 2, pp. 131-138 (2020).
8. Suryadi, D, "Promosi Efektif Menggugah Minat & Loyalitas Pelanggan", Jakarta: PT. Suka Buku (2011).
9. Hanifah, "Implementasi Model APOS pada Matakuliah Kalkulus Integral pada Pokok Bahasan Fungsi Transenden di Prodi Pendidikan Matematika FKIP UNIB TA 2017/2018", Conference on Mathematics, Science, and Education (2017).
10. Hanifah, "Model APOS Inovasi Pada Pembelajaran Matematika", FKIP Press (2016).
11. Hanifah and Irsal, N.A., "The Effectivity of APOS Model Based Worksheets On The Improper Integral", Journal of Physics: Conference. Series. 1317012115, pp. 1–10 (2019).
12. Plomp, T., and Nieveen, N., "Educational Design Research", Enchede: Netherlands Institute for curriculum development (2013).
13. Retnawati, H., "Membuktikan Validitas Instrumen dalam Pengukuran" (2014), diakses di: http://www.evaluation-edu.com.
14. Widoyoko, E.P., "Evaluasi Program Pembelajaran", Yogyakarta: PustakaPelajar (2009).
15. Yudha, S. F. A., Yulkifli and Yohandri, "Validity of Student Worksheet Based on Guided Inquiry Learning Model Assisted by Digital Practicum Tool", Journal of Physics: Conference Series, pp. 1–7 (2019).

16. Lestari, H. P., Sugiyono and Listiyani, E., “Development of Geogebra-assisted Student Worksheet for Transformational Geometry Learning”, Journal of Physics: Conference Series, pp. 1–9 (2020).
17. Sudihartinih, E. and Purniati, T., “February Using Geogebra to Develop Students Understanding on Circle Concept”, In J. Phys. Conf. Ser. 1157, pp. 042090 (2019).
18. Zulnaidi, H., Oktavika, E., and Hidayat, R., “Effect of Use of Geogebra on Achievement of High School Mathematics Students”, Educ. Inf. Technol, Vol. 25, pp. 51-72 (2020).
19. Yorganci, S., “A study on the views of graduate students on the use of Geogebra in mathematics teaching” Eur. J. Educ. Stud. (2018).