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DEVELOPMENT OF AN APPLICATION OF CRITICAL THINKING SKILLS TOOLS USING FUZZY EXPERT SYSTEM

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Abstract

This research aims to determine the value of the students' critical thinking skills by using fuzzy expert systems. The system is utilised in the research to obtain an objective and authentic assessment in an abstract or ambiguous assessment. The method used is a mixed method. To get the value of the input of fuzzy expert system variables, the research employs test and performance assessments promoting critical thinking skills. Research results show the value of students' critical thinking skills are more fair, objective, and accurate. The accuracy value is supported by the results of a questionnaire given that the value of critical thinking skills acquired is influenced by the habit of students in dealing with questions that contain critical thinking skills. This paper concluded that, even though students' critical thinking skills have not been increased optimally, the application developed had successfully promoted critical thinking skills as all the indicators and criteria were covered.

Keywords: Critical thinking skills, Fuzzy expert system, Performance assessment.

1. Introduction

Critical thinking is a thinking skill that includes interpreting, analysing, and evaluating assumptions, values, ideas, hidden thoughts and arguments [1, 2]. Critical thinking, when linked to the revised edition of Bloom's taxonomy, is the top cognitive process of analysing and evaluating [3]. According to Ennis [4], critical thinking is the ability to think rationally and reflectively to decide something based on what must be trusted and done. However, sometimes the term critical thinking is considered "negative" as if its definition leads to sharply criticizing the arguments and ideas of others [1, 2]. In fact, critical thinking is a Higher Order Thinking Skill that needs to be improved and developed in every human being because human resources will have better quality [5].

Based on studies by Perkins and Murphy [6], higher-order thinking skills, which include critical thinking skills are often associated with educational goals or outcomes. Therefore, it is necessary to develop evaluations of students' critical thinking to know their abilities. There are several critical thinking evaluation instruments developed: Open-ended essays [7], test [5, 8-10] in the form of multiple choices [11, 12], and structured questionnaire [13]. In addition, the assessment of critical thinking can use authentic judgement [14]. Authentic assessment can form high-level thinking skills, which basically is a learning assessment that leads to the real-world context [15-17].

In decision-making, the assessment of critical thinking developed in this study uses fuzzy logic. Fuzzy logic is used because it can provide a wider range of values, which in practice often arise when dealing with ambiguous assessment situations [18]. According to Bouslama et al. [19], Saputra et al. [20], Chen and Li [21], Yang et al. [22] and Tay and Lim [23], nowadays, the use of fuzzy logic in the student assessment process has been developed by several experts. The fuzzy logic developed in the assessment by applying it to fuzzy expert systems. The application of fuzzy expert systems produces assessment tools that are more objective or authentic and flexible compared to conventional or classical assessments [24-29].

The main purpose of the study was to develop an application of fuzzy expert systems, which aim to promote students' critical thinking skills.

2. Research Method

The procedure used in this study can be broadly seen in the flow diagram of Fig. 1, generally containing research procedures starting from the stage of literature study, making and testing assessment instruments, making and testing assessment tools to preparing reports.

This research begins with the stages of conducting literature studies including reading and studying various journals and books that relate to the assessment of critical thinking skills, fuzzy logic, and the application of fuzzy logic in student assessment. After that, it continues by searching an instrument for assessing critical thinking skills based on the references that have been obtained. The instrument made in the assessment of critical thinking skills is by using a performance task [14]. The instrument developed is an adopted and adapted model to identify involvement in critical thinking as shown in Table 1 [6]. The instrument developed on the subject matter of the discussion of the Electrical Circuit Basics in the Electrical Engineering Basic course.

When the instrument is finished, then an expert judgment is carried out to find out whether the instrument is valid or not. If there are still deficiencies, it will be revised until the assessment instrument is said to be valid.

The next stage is the creation of an assessment tool for critical thinking skills using a Fuzzy Expert System (FES). In making an assessment tool for critical thinking skills using FES, an understanding of fuzzy set theory is needed. Suppose U is a universe object and x is a member of U. A fuzzy set A in U is defined as a membership function $\mu_A(x)$, which maps each object in U to a real value in intervals [1] can be defined as follows [20, 30]:

$$\mu_A: U \rightarrow [0,1] \quad (1)$$

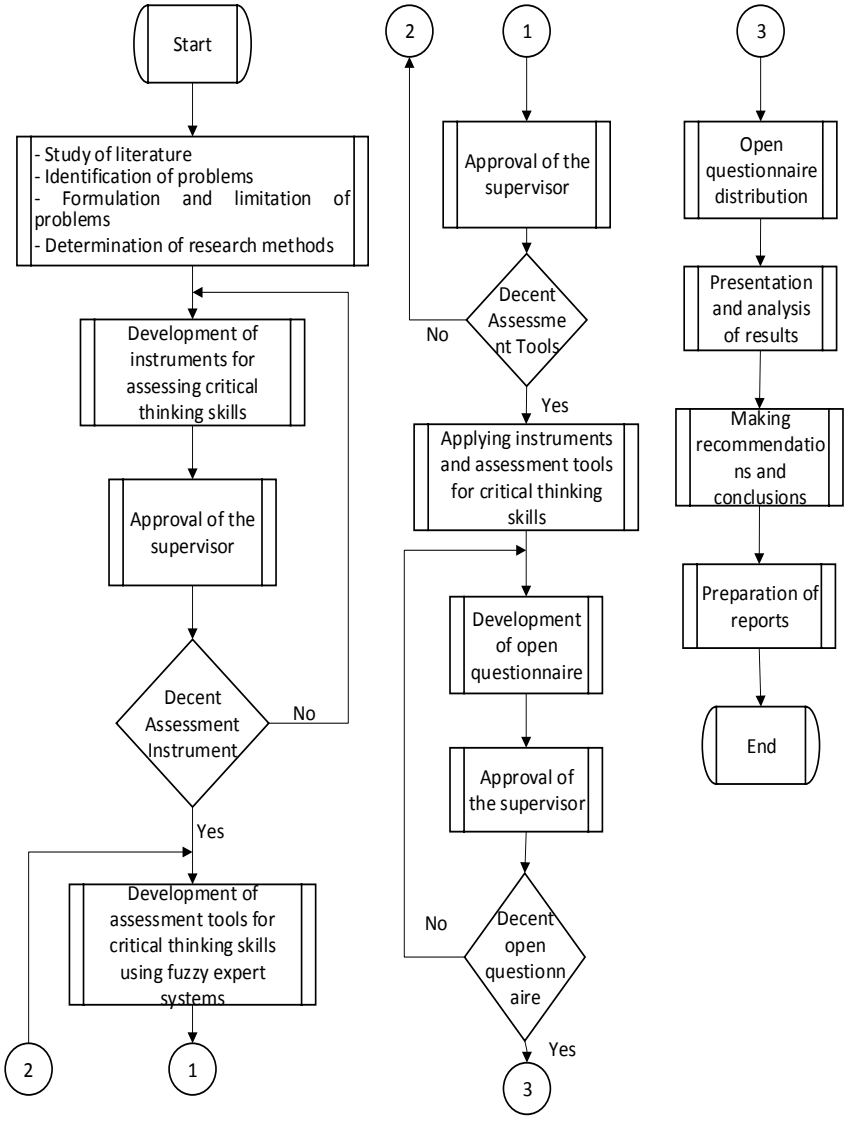


Fig. 1. Flowchart of research procedure.

Table 1. Grid of instruments for assessing critical thinking skills.

Aspects	Indicator
Clarification	Mention and write down things that are known in a problem
	Mention and write down the things asked in a problem
Assessment	Use the relevant information in solving problems
Inference	Explain the settlement strategy
	Make the right conclusion
Strategy	Find and explain other strategies for solving problems

The values $\mu_A(x)$ state the degree of membership x in A is stated as follows [20, 30]:

$$A = \{(x, \mu_A(x))/x \in U\} \quad (2)$$

Writing a "/" sign represents a partner or relationship of an element with its straightforward element. The convention for producing fuzzy sets produced from discrete U universes is as follows [20, 30]:

$$A = \int_{x \in U} \mu_A(x)/x \quad (3)$$

Making FES for evaluating students' critical thinking skills has 3 main stages presented in Fig. 2 [30]:

- Crisp input: The value of input whose truth is certain from the results of evaluating students' critical thinking skills.
- Fuzzification: The process of converting the crisp input into a fuzzy input in the form of linguistic values based on membership functions (MF).
- Inference: The reasoning process uses fuzzy input and fuzzy rules that have been made to produce fuzzy output.
- Defuzzification: The process of changing a fuzzy output becomes a crisp value based on the membership function that has been created.
- Crisp value: The actual output value is definite to show the value of evaluating students' critical thinking skills.

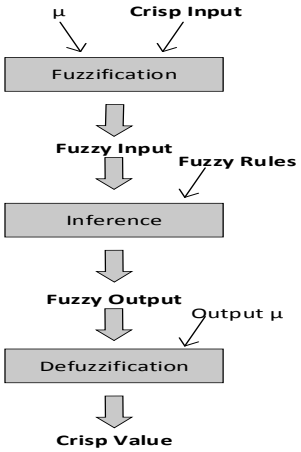


Fig. 2. Fuzzy expert system architecture.

FES was made using five linguistic variables as input and output, namely Very Good (VG), Good (G), Fair (F), Less (L) and Very Less (VL). Variables that state critical thinking skills into the input with fuzzy logic processes will produce the value of critical thinking skills as output. Assessment of students' critical thinking skills has four main variables, namely clarification, assessment, inference, and strategy [6]. These four variables become FES inputs, which will be processed by fuzzy rules and produce output values of students' critical thinking skills. Thus, block diagrams can be made to assess critical thinking skills such as Fig. 3 [19, 24, 25].

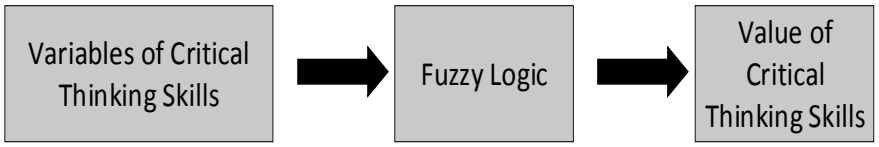


Fig. 3. Block diagram assessment of critical thinking skills using FES.

The membership function type used is the Gaussian curve because with these curves all points are defined and have a smooth curve [31, 32]. This FES model has a universal range of speech that is used starting from zero to one hundred with a membership function that can be written with the following approach:

$$G_{SK}(x;k,\gamma)\{e^{-10(-x)^2} \quad 0 \le x \le 100 \tag{4}$$

$$G_{K}(x;k,\gamma)\{e^{-10(25-x)^2} \quad 0 \le x \le 100 \tag{5}$$

$$G_{C}(x;k,\gamma)\{e^{-10(50-x)^2} \quad 0 \le x \le 100 \tag{6}$$

$$G_{B}(x;k,\gamma)\{e^{-10(75-x)^2} \quad 0 \le x \le 100 \tag{7}$$

$$G_{SB}(x;k,\gamma)\{e^{-10(100-x)^2} 0 \le x \le 100 \tag{8}$$

To explain more about the above hypothesis, it can be seen the value of each linguistic variable in Fig. 4.

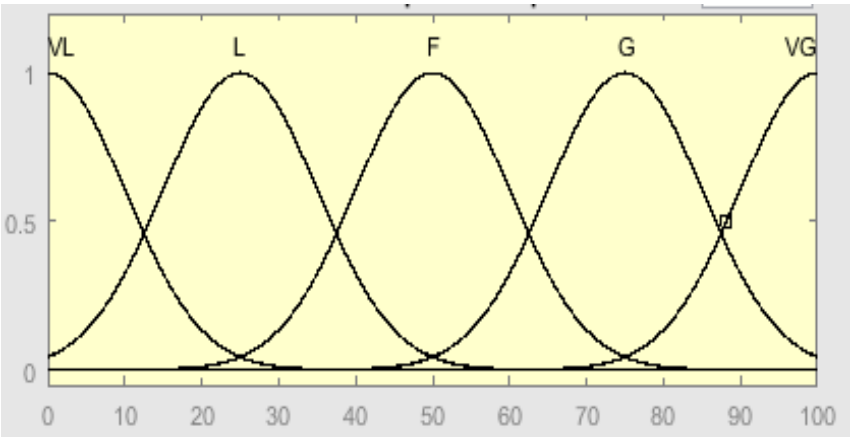


Fig. 4. Gaussian membership function.

One factor that greatly influences the results of fuzzy output is the fuzzy rules that are made. In fuzzy expert systems, it has a maximum number of rules that are made so that all possible conditions can be entered are 5^4 = 625 "IF-THEN" rules [32]. To determine these rules, it is necessary to interpret the input of linguistic variables, namely VG = 0; G = 1; F = 2; L = 3; and VL = 4. The average value $(\bar{x})$ of the input of linguistic variables is used as a determinant of the output value with the following conditions:

IF	$0 \leq (\bar{x})\ input\ \leq 0{,}75$	THEN output = VG
IF	$0{,}75 < (\bar{x})\ input\ \leq 1{,}75$	THEN output = G
IF	$1{,}75 < (\bar{x})\ input\ \leq 2{,}75$	THEN output = F
IF	$2{,}75 < (\bar{x})\ input\ \leq 3{,}75$	THEN output = L
IF	$3{,}75 < (\bar{x})\ input\ \leq 4$	THEN output = VL

The process of fuzzification, inference (rule base), and defuzzification will be carried out using the Matlab software version 2015. The method used in the inference is the Mamdani method. The use of the Mamdani method can provide an output that is more intuitive and more in line with the human mindset [30, 32]. Defuzzification and surface viewer are outputs that can be generated from the software. A surface that has a smooth colour gradation indicates better assessment rules [20]. After completing the steps of making the tool, the equipment was tested for feasibility by looking at the smoothness of the surface colour changes produced and expert judgement by supervisors.

After the instrument and assessment tools for critical thinking skills are declared feasible, then the instruments and tools are applied to students of the Department of Electrical Engineering Education who contract Basic Electrical Engineering subjects. The assessment instrument created will produce the value of each of the critical thinking skills variables that are input for FES. After the input variable is entered in FES, the value of critical thinking skills will appear. Furthermore, an open questionnaire was distributed to the students to find out the responses of students to the instruments given. It can even be possible to find new findings from the questionnaires distributed.

Presentation and analysis of results are obtained from the value of students' critical thinking skills and open questionnaires. The analysis is presented in the form of numbers, tables, images, and descriptions; data reduction. Recommendations are made to provide recommendations on what things should be done with this research and subsequent research so that the results can be much better. Conclusions are made to express the results of this study in brief. If all research procedures are completed, the final step is preparing the report as evidence of research responsibility.

3. Results and Discussion

To make sure the results and discussion section, a list of questions prepared for the assessment of critical thinking skills adjusting to the criteria or aspects in measuring critical thinking skills is prepared. The questions are (1) What do you know about the problem? (2) What questions arise from the problems? (3) What is the power of each lamp Mr. Toni set up? (4) What are the voltage and current of the lamp if Pak Toni installs the lamps in a parallel way? How is the condition of each lamp? (5) What can you conclude? and (6) Do you have another strategy of calculating

the voltage and current on both serial and parallel instalment? If you do, please write it down. These aspects are clarification, assessment, inference, and strategy. Questions compiled in the Basic Electrical Engineering course with the subject matter of the Electrical Circuit Basics on the topic taken regarding the relationship of series or voltage dividers and parallel relations or current dividers. One characteristic of the problem that contains HOTS is the context of the problem associated with real conditions or everyday life. In the context of the questions provided, the installation of electricity is given.

The following are some of the results of the work of students in working on the assessment questions of critical thinking skills shown in Fig. 5. The figure shows that each student has their own styles of figuring out the problems they face. Some of them made a mind map, some of them came up with a more narrative way, and some directly gave their proposed formula.

The assessment of students' critical thinking skills has four main variables, namely clarification, assessment, inference and strategy [6].

The four variables become FES inputs, which will be processed by fuzzy rules and produce output values of students' critical thinking skills. The variables presented have been declared feasible to be used in research by supervisors. Then, a block diagram can be made for the assessment of critical thinking skills such as Fig. 6.

The maximum number of rules that can be made $n^x = 5^4$ is the 625 "IF-THEN" rule. Of the 625 rules, "IF-THEN" is carried out an analysis of the possible rules that occur. In this study, the input variables used have relevance to other inputs. The input of the last linguistic variable cannot be greater if the three initial input linguistic variables are very small. This also applies to previous linguistic variables because in this study the critical thinking skills assessment instrument has stages, namely the clarification stage → the assessment stage → the inference stage → the strategy stage. Then, the "IF-THEN" rule that can be used is 70 "IF-THEN" rules and in determining the applicable rules there are certain patterns to decide.

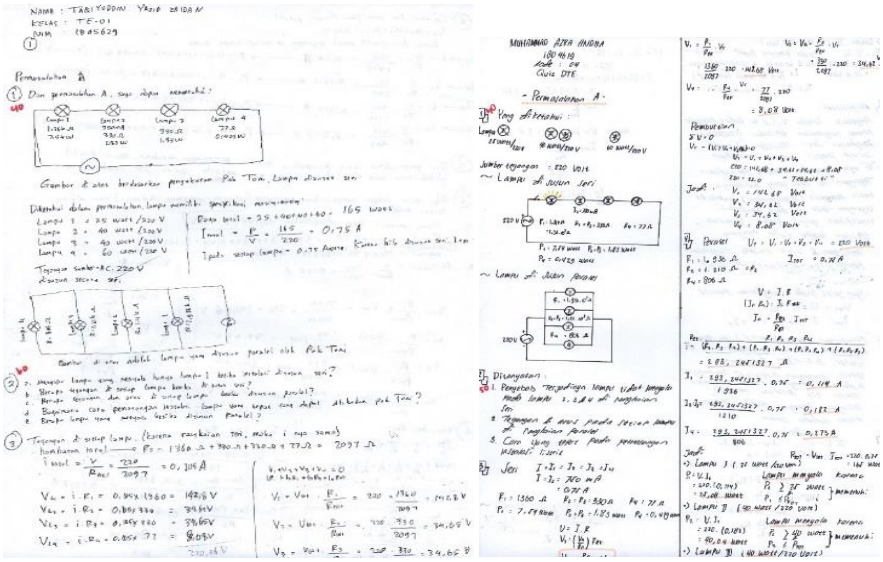


Fig. 5. Student answer sheet.

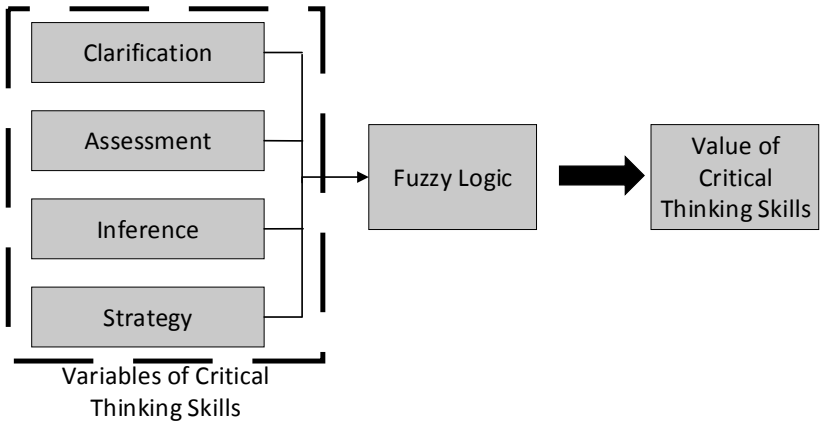
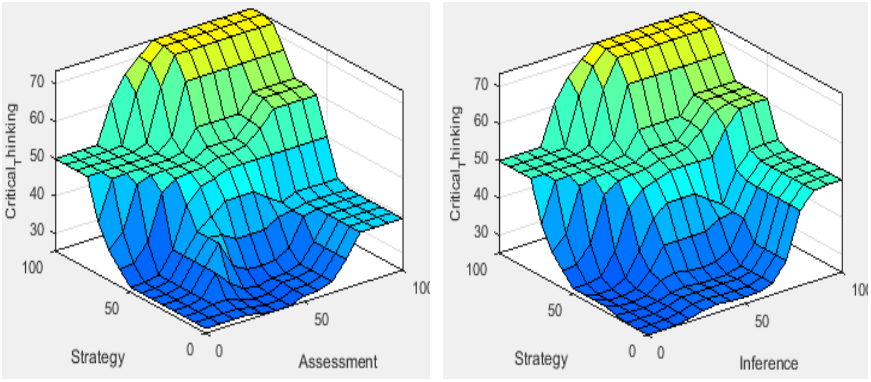


Fig. 6. Block diagram assessment of critical thinking skills using FES.

The results of the inference (rule base) on the FES designed in this study can be seen in Figs. 7(a) and (b). Figures 7(a) and (b) have almost the same contour. There are obvious differences in the colour changes that form the contour of the steps in the assessment and inference values that are high. In the assessment value that is high, the value of critical thinking is still low. Meanwhile, in the inference value, the higher critical thinking value is higher than the assessment. Figure 7(a) is the surface of the rules for inputting strategy variables and assessments of the output of critical thinking values. Whereas, Fig. 7(b) is the surface of the rules for inputting strategic variables and inference to the output of critical thinking values. Some of the surfaces produced have subtle colour gradations. That is because the rules made on the input variables used are interrelated.

The assessment variables of critical thinking skills, namely aspects of clarification, assessment, inference, and strategy obtained from the instrument of assessment of critical thinking skills are entered the rule viewer in the Matlab software as input. After that, the value of critical thinking skills will appear as shown in Fig. 8. In this figure, the relationship between rules (fuzzy rules) is presented to get the value of critical thinking skills from the defuzzification process.



(a) (b)

Fig. 7. Surface viewer.

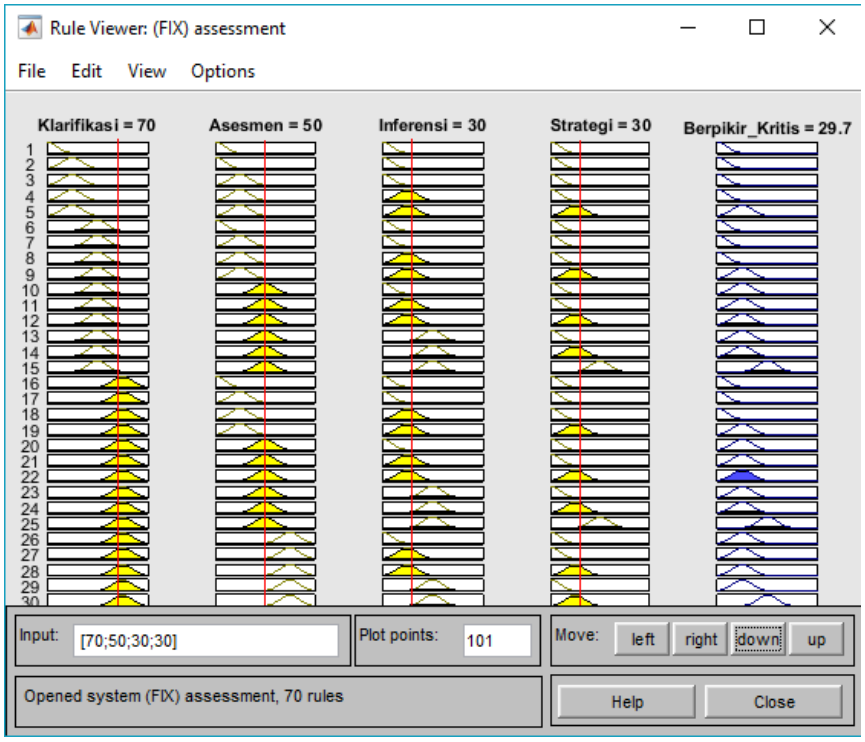


Fig. 8. Assessment of critical thinking skills using FES.

The following are the assessment results obtained from the instruments that have been given to students as shown in Table 2.

Table 2 shows the results of the analysis of values that are interpreted in the assessment of rigid rules. Table 2 shows that there are still many students whose grades of critical thinking skills are ugly/failed (E), which are as many as 28 (87.5% of the total students). In other words, 28 students failed in working on the questions given. Meanwhile, students who can be said to be successful in working on the problem are only four people (12.5%). Of all four people considered successful, two were classified as Good and the other two were actually under Good, yet they are still considered successful.

Table 2 shows that the causes of failure or poor values obtained can be seen from where the majority of students are unable to fulfil the assessment aspects of the strategy. As many as 93.75% of students failed or their grades were poor in the aspect of strategy. Whereas 6.25% or 2 students are still lacking in fulfilling the assessment of strategy aspects. Aspects that greatly influence the assessment of the aspects of the strategy are aspects of 'assessment' assessment, namely students provide relevant information to solve problems in the problem.

In the data presented in the assessment aspects of the assessment, the majority of students were not able to fulfil it completely. Students, who are able to do very well or completely, fulfil the assessment aspects, are only 6.25% (2 people) of all. The remaining 93.75% of students cannot complete the

assessment aspects. More specifically, 40,625% of students failed/ were poor in aspects of 'assessment' assessment.

Another aspect is the aspect of inference. It actually evaluates the ability of students to solve problems and express conclusions from problems when the questions are given. Students who are able to succeed at this stage are 71.875% or 23 people. The remaining nine students failed/poorly fulfilled aspects of the assessment. In addition, there are other factors that can be obtained from Table 2 data, in which, all students are only able to fulfil the aspect of assessment clarification in solving the questions given. However, there are still students who are lacking in fulfilling these aspects, which is 15.625%. Aspects of the assessment of clarification are only limited to writing data and information obtained or found in the problems of the questions given.

In qualitative data analysis conducted, in this case, the low value of students' critical thinking skills is supported by their unfamiliarity in dealing with or solving problems or problems that contain the value of critical thinking skills. They are accustomed to getting questions that have problems directly at the point. Meanwhile, the questions that contain the value of critical thinking skills involve real-world contexts that require more understanding to get data and information in solving problems. In other words, data and information are not directly given. With that, students need a longer time to work on the questions. Even though they remember the related formulas, if they are not used to working on similar questions, it will be difficult for them to do. In relation to the low critical thinking abilities, studies have shown that it happens to both high achiever students [33] and low achiever ones [34]. Other studies also proved that in the 21st-century era, the digital application plays an important role in promoting students' critical thinking skills [35, 36].

Table 2. Data on assessment of critical thinking skills using FES.

Final decision	Assessment aspect								Value of critical thinking skills	
	Clarification		Assessment		Inference		Strategy			
	Total (person)	(%)	Total (person)	(%)	Total (person)	(%)	Total (person)	(%)	Total (person)	(%)
A	9	28,13	2	6,25	1	3,125	0	0	0	0
A-	2	6,25	1	3,125	0	0	0	0	0	0
B+	2	6,25	2	6,25	1	3,125	0	0	0	0
B	4	12,5	2	6,25	2	6,25	0	0	1	3,125
B-	5	15,63	2	6,25	2	6,25	0	0	1	3,125
C+	3	9,375	6	18,75	3	9,375	0	0	0	0
C+	2	6,25	1	3,125	5	15,63	0	0	0	0
D	5	15,63	3	9,375	9	28,13	2	6,25	2	6,25
E	0	0	13	40,63	9	28,13	30	93,75	28	87,5

Students have responses that are able to solve the questions given, which contain critical thinking skills. In doing so, they must understand the problems that are given well, process and analyse data and information carefully, and are required to imagine. In addition, students must reflect on what conclusions are obtained in the problem. Students agree that this is necessary so that they are able to understand the purpose of the problem in the given question. Students are also required to find problem-solving in various ways, so students can assess, which solutions are more effective. However, stu dents prefer questions that directly address the core of the problem or directly given related points in solving the problem since those kinds of questions are considered easier to do than questions that contain critical thinking skills. This way, students are expected to become independent learners since the learning is turning from teacher-centred into learner-centred and even learning-centred [37-44].

4. Conclusion

Based on the results and discussion of the study, this research concluded that the application developed was effective in promoting critical thinking skills because it has fulfilled the criteria aspects in identifying critical thinking skills, namely, aspects of clarification, assessment, inference, and strategy. Then, the creation of a critical thinking skills assessment tool using FES, which was assisted by Matlab software, was able to represent the value of critical thinking skills. With the making of fuzzy rules that are good and correct, it can produce a good surefire, which is a smooth colour gradation. As for critical thinking skills, it has been found that students prefer questions that directly address the core of the problem or directly given related points in solving problems rather than questions that contain critical thinking skills. Questions that contain critical thinking skills are more difficult to do and require a long time to work on. However, most students share the same opinion that questions promoting critical thinking are more effective to trigger their critical ability since they enable them to really understand the real problems.

References

1. Fisher, A. (2008). *Berpikir kritis. Sebuah pengantar*. Jakarta, Indonesia: Erlangga.
2. Kuswana, W.S. (2011). *Taksonomi berpikir*. Bandung, Jawa Barat, Indonesia: PT. Remaja Rosdakarya.
3. Jailani; Sugiman; Retnawati, H.; Bukhori; Apino, E.; Djidu, H.; and Arifin, Z. (2018). *Desain pembelajaran matematika untuk melatihkan higher order thinking skills*. Yogyakarta, Indonesia: UNY Press.
4. Ennis, R.H. (1994). The nature of critical thinking: An outline of critical thinking dispositions and abilities. *Proceedings of the Sixth International Conference on Thinking*. Cambridge, United Kingdom, 8 pages.
5. Arifin, Z. (2016). Pengembangan instrumen pengukur berpikir kritis matematika siswa SMA kelas X. *Jurnal Theorems (The Original Research of Mathematics)*, 1(1), 58-74.
6. Perkins, C.; and Murphy, E. (2006). Identifying and measuring individual engagement in critical thinking in online discussions: An exploratory case study. *Journal of Educational Technology and Society*, 9(1), 298-307.

7. Sugiarti, T.; Kaniawati, I.; and Aviyanti, L. (2017). Development of assessment instrument of critical thinking in Physics at Senior High School. *Journal of Physics: Conference Series*, 812(1), 012018.
8. Lloyd, M.; and Bahr, N. (2010). Thinking critically about critical thinking in higher education. *International Journal for the Scholarship of Teaching and Learning*, 4(2), 18 pages.
9. Bensley, D.A.; Rainey, C.; Murtagh, M.P.; Flinn, J.A.; Maschiocchi, C.; Bernhardt, P.C.; and Kuehne, S. (2016). Closing the assessment loop on critical thinking: The challenges of multidimensional testing and low test-taking motivation. *Thinking Skills and Creativity*, 21, 158-168.
10. Zulfaneti; Edriati, S.; and Mukhni. (2018). Enhancing students' critical thinking skills through critical thinking assessment in calculus course. *Journal of Physics: Conference Series*, 948(1), 012031.
11. Nurismawati, R.; Sanjaya, Y.; and Rusyati, L. (2018). The relationship between students critical thinking measured by science virtual test and students logical thinking on eighth-grade secondary school. *Journal of Physics: Conference Series*, 1013(1), 012071.
12. Ekayanti, A. (2014). *Profil keterampilan berpikir kritis siswa SMA pada Materi Termokimia*. Disertasi Thesis. Fakultas Pendidikan Matematika dan Ilmu Pengetahuan Alam, Universitas Pendidikan Indonesia, Bandung, Indonesia.
13. Kumar, R.; and James, R. (2015). Evaluation of critical thinking in higher education in Oman. *International Journal of Higher Education*, 4(3), 33-43.
14. Pratama, L.D.; and Lestari, W. (2017). Kemampuan berpikir kritis siswa dalam menyelesaikan soal performance task. *Prosiding Seminar Matematika dan Pendidikan Matematika UNY.* Yogyakarta, Indonesia, 415-420.
15. Ermawati, S.; and Hidayat, T. (2017). Penilaian autentik dan relevansinya dengan kualitas hasil pembelajaran (Persepsi Dosen dan Mahasiswa IKIP PGRI Bojonegoro). *Jurnal Pendidikan Ilmu Sosial*, 27(1), 92-103.
16. Muchtar, H. (2010). Penerapan penilaian autentik dalam upaya peningkatan mutu pendidikan. *Jurnal Pendidikan Penabur*, 14(9), 68-76.
17. Pantiwati, Y. (2016). Hakekat asesmen autentik dan penerapannya dalam pembelajaran biologi. *Jurnal Edukasi Matematika dan Sains*, 1(1), 18-27.
18. Subbotin, I.Y.; and Voskoglou, M.G. (2016). An application of the generalized rectangular fuzzy model to critical thinking assessment. Retrieved October 2018, from https://arxiv.org/ftp/arxiv/papers/1601/1601.03065.pdf.
19. Bouslama, F.; Housley, M.; and Steele, A. (2014). A fuzzy logic-based emotional intelligence framework for evaluating and orienting new students at HCT Dubai colleges. *Proceedings of the 14th International Conference on Hybrid Intelligent Systems.* Kuwait, 85-90.
20. Saputra, D.I.; Abdullah, A.G.; and Hakim, D.L. (2013). Pengembangan model evaluasi pembelajaran project based learning berbasis logika fuzzy. *Innovation of Vocational Technology Education*, 9(1), 13-34.
21. Chen, S.-M.; and Li, T.-K. (2011). Evaluating students' learning achievement based on fuzzy rules with fuzzy reasoning capability. *Expert Systems with Applications*, 38(4), 4368-4381.

22. Yang, Z.; Zhang, Y.; Rong, R.; and Zou, X. (2010). The multi-level fuzzy evaluation model of college students' comprehensive quality. *Proceedings of the 2nd International Conference on Information Science and Engineering*. Hangzhou, China, 3279-3282.
23. Tay, K.M.; and Lim, C.P. (2011). A fuzzy inference system-based criterion-referenced assessment model. *Expert Systems with Applications*, 38(9), 11129-11136.
24. Petrudi, S.H.J.; Pirouz, M.; and Pirouz, B. (2013). Application of fuzzy logic for performance evaluation of academic students. *Proceedings of the 13th Iranian Conference on Fuzzy Systems (IFSC).* Qazvin, Iran, 1-5.
25. Yadav, R.S.; and Singh, V.P. (2011). Modeling academic performance evaluation using soft computing techniques: A fuzzy logic approach. *International Journal on Computer Science and Engineering (IJCSE)*, 3(2), 676-686.
26. Yadav, R.S.; Soni, A.K.; and Pal, S. (2014). A study of academic performance evaluation using fuzzy logic techniques. *Proceedings of the International Conference on Computing for Sustainable Global Development (INDIACom). New Delhi, India*, 54-59.
27. Patil, S.; Mulla, A.; and Mudholkar, R.R. (2012). Best student award - a fuzzy evaluation approach. *International Journal of Computer Science and Communication*, 3(1), 9-12.
28. Surya, A.A.; Kurian, M.K.; and Varghese, S.M. (2016). Overall performance evaluation of engineering students using fuzzy logic. *International Journal on Cybernetics and Informatics (IJCI)*, 5(2), 71-78.
29. Sakthivel, E.; Kannan, K.S.; and Arumugam, S. (2013). Optimized evaluation of students performances using fuzzy logic. *International Journal of Scientific and Engineering Research*, 4(9), 1128-1133.
30. Suyanto. (2014). *Artificial Intelligence*. Bandung, Indonesia: Informatika.
31. Viattchenin, D.A.; Tati, R.; and Damaratski, A. (2013). Designing Gaussian membership functions for fuzzy classifier generated by heuristic possibilistic clustering. *Journal of Information and Organizational Sciences*, 37(2), 127-139.
32. Kustiawan, I.; and Chi, K.-H. (2015). Handoff decision using a Kalman filter and fuzzy logic in heterogeneous wireless networks. *IEEE Communications Letters*, 19(12), 2258-2261.
33. Williams, R.L.; and Stockdale, S.L. (2003). High-performing students with low critical thinking skills. *The Journal of General Education*, 52(3), 199-225.
34. Zohar, A.; and Dori, Y.J. (2003). Higher order thinking skills and low-achieving students: Are they mutually exclusive? *The Journal of the Learning Sciences*, 12(2), 145-181.
35. Yang, Y.-T.C.; and Wu, W.-C.I. (2012). Digital storytelling for enhancing student academic achievement, critical thinking, and learning motivation: A year-long experimental study. *Computers and Education*, 59(2), 339-352.
36. Kivunja, C. (2014). Do you want your students to be job-ready with 21st century skills? Change pedagogies: A pedagogical paradigm shift from vygotskyian social constructivism to critical thinking, problem solving and siemens' digital connectivism. *International Journal of Higher Education*, 3(3), 81-91.

37. Paul, R. (1990). Towards a new measure of success: Developing independent learners. *Open Learning: The Journal of Open, Distance and e-Learning*, 5(1), 31-38.
38. Christie, H.; Barron, P.; and D'Annunzio-Green, N. (2013). Direct entrants in transition: Becoming independent learners. *Studies in Higher Education*, 38(4), 623-637.
39. Kirkwood, A. (2008). Getting it from the web: Why and how online resources are used by independent undergraduate learners. *Journal of Computer Assisted Learning*, 24(5), 372-382.
40. Amelia, N.; Abdullah, A.G.; and Mulyadi, Y. (2019). Meta-analysis of student performance assessment using fuzzy logic. *Indonesian Journal of Science and Technology*, 4(1), 78-88.
41. Abdullah, A.G.; and Putra, A.P. (2017). Water level measurement altitude trainer integrated with human machine interface. *Indonesian Journal of Science and Technology*, 2(2), 197-210.
42. Nandiyanto, A.B.D.; Asyahidda, F.N.; Danuwijaya, A.A.; Abdullah, A.G.; Amelia, N.; Hudha, M.N.; and Aziz, M. (2018). Teaching "nanotechnology" for elementary students with deaf and hard of hearing. *Journal of Engineering Science and Technology* (*JESTEC*), 13(5), 1352-1363.
43. Wahyu, W.; Suryatna, A.; and Kamaludin, Y.S. (2018). The suitability of William's creativity indicators with the creativity-based worksheet for the junior high school students on designing simple distillation tool. *Journal of Engineering Science and Technology* (*JESTEC*), 13(7), 1959-1966.
44. Haristiani, N.; Aryanti, T.; Nandiyanto, A.B.D.; and Sofiani, D. (2017). Myths, islamic view, and science concepts: The constructed education and knowledge of solar eclipse in Indonesia. *Journal of Turkish Science Education*, 14(4), 35-47.