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Development of Students Worksheet Based STEM (Science, Technology, Engineering, and Mathematics) to Improve Student Critical Thinking Skill In Reaction Rate

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Abstract: Development of Students Worksheet Based STEM (Science, Technology, Engineering, and Mathematics) to Improve Student Critical Thinking Skill In Reaction Rate. The aim of this study is to know the feasibility of students' worksheets based on STEM to improve the ability of critical thinking on the reaction rate matter. The study uses a Research and Development (R & D) design until the limited testing phase. The trial was conducted on 15 students in class XI MIA 6 Senior High School Hang Tuah 2 Sidoarjo. The instruments used are review and validation sheets, student response questionnaire sheets, knowledge, and critical thinking skills test sheets. The STEM-based Student Worksheets are feasible based on validity, practicality, and effectiveness aspect. Validity is reviewed based on content and construct with percentage each criterion are 81,25% (very valid) and 80,69% (valid). Practicality based on student responses shows of percentage 86,67% with very practice category. Effectivity based on results of knowledge and critical thinking skills tests with Wilcoxon test each show sig. (2-tailed) the score is 0,001 the meaning is before and after students have student worksheets is different, and the results of knowledge and critical thinking skills n-gain show 0,78 and 0,87 with high category. The n-gain results of critical thinking skills interpretation are 0,94, analysis is 0,76, and inferention is 0,86 with high category. So it can be concluded that STEM-based worksheets are feasible and can improve students' critical thinking skills.

Keywords: Student Worksheets, STEM, Critical Thinking Skills, Reaction Rates

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Abstrak: Pengembangan LKPD Berbasis STEM (Science, Technology, Engineering, and Mathematics) untuk Meningkatkan Keterampilan Berpikir Kritis Peserta Didik pada Materi Laju Reaksi. *Penelitian ini bertujuan untuk mengetahui kelayakan LKPD berbasis STEM untuk meningkatkan keterampilan berpikir kritis peserta didik pada materi laju reaksi. Desain penelitian ini adalah Research and Development (R&D) yang dibatasi sampai tahap uji coba terbatas. Uji coba terbatas dilakukan pada 15 peserta didik kelas XI IPA 6 SMA Hang Tuah 2 Sidoarjo. Instrumen yang digunakan dalam penelitian ini adalah lembar telaah, lembar validasi, lembar angket respon peserta didik, lembar tes ranah pengetahuan dan keterampilan berpikir kritis. Hasil penelitian menunjukkan bahwa LKPD berbasis STEM layak, ditinjau dari aspek validitas, kepraktisan dan keefektifan. Aspek validitas ditinjau dari validitas isi dan konstruk mendapatkan persentase masing-masing sebesar 81,25% (sangat valid) dan 80,69% (valid).*

Aspek kepraktisan ditinjau dari hasil angket respon peserta didik mendapatkan persentase sebesar 86,67% dengan kategori sangat praktis. Aspek kefektifan ditinjau dari hasil tes ranah pengetahuan dan keterampilan berpikir kritis dengan uji Wilcoxon masing-masing mendapatkan nilai sig. (2-tailed) sebesar 0,001 yang berarti terdapat perbedaan rata-rata nilai antara sebelum dan sesudah diberikannya LKPD, serta hasil n-gain ranah pengetahuan dan keterampilan berpikir kritis menunjukkan peningkatan masing-masing sebesar 0,78 dan 0,87 dengan kategori tinggi. Hasil n-gain ranah keterampilan berpikir kritis pada indikator interpretasi sebesar 0,94, analisis sebesar 0,76, dan inferensi 0,86 dengan kategori tinggi. Sehingga dapat disimpulkan bahwa LKPD berbasis STEM layak dan dapat meningkatkan keterampilan berpikir kritis peserta didik.

Kata kunci: *Lembar Kerja Peserta Didik, STEM, Keterampilan Berpikir Kritis, Laju Reaksi.*

▪ INTRODUCTION

Chemistry is a lesson about phenomena and natural laws, including the composition, character, and energy of a material (Rahmawati, Ramadhani, & Afrizal, 2020). Chemistry is quite difficult to understand because it has an abstract concept (Ristiyani & Bahriah, 2016). So that students are always to remem facts by ignoring concepts (Rahmawati, Ramadhani, & Afrizal, 2020). The results of the Program for International Student Assessment (PISA) 2018 found that Indonesia ranks 71st out of 79 countries in the category of scientific ability (Hewi & Shaleh, 2020). So, the critical thinking skills are categorized as low.

The STEM approach is an alternative to practice critical thinking skills because it is an interdisciplinary approach that combines science, technology, engineering, and mathematics into teaching and learning activities. The STEM approach challenges students to make connections between what they learn in class and the real world (Siew & Ambo, 2018). Thus, it can train students' critical thinking skills, logic, and systematic so that they can face global challenges (Nessar, Yusuf, & Cecil, 2017).

The STEM approach can be combined with student worksheets. Student worksheets need to be developed because they can be used as a learning strategy that is innovative, constructive, and involves students actively so the competencies can be achieved (Lestari, Astuti, & Darsono, 2018). STEM-based worksheets can be implemented in chemistry subjects. Chemistry learning is expected to be carried out by the 2013 curriculum. The 2013 curriculum is a curriculum that combines the importance of chemistry soft skills and hard skills with the role of students as subjects and not as objects. This means that students actively construct their knowledge or what is commonly referred to as student-centered. However, the reality is that chemistry learning in the field has not yet reached the demands of the 2013 curriculum, this is based on the results of pre-research at Hang Tuah 2 High School Sidoarjo. The results from teacher interviews, response questionnaires, and tests of students' critical thinking skills that some students were less active, most students considered chemistry quite difficult to understand, especially the reaction rate material. They consider the material to be too much memorization, counting and some consider the material to be less meaningful and boring. In addition, the students' critical thinking skills got an average score of 32.33. The teacher uses student worksheets media in the form of simple questions and has never developed a STEM-based student worksheet.

The STEM-based student worksheet can improve students' conceptual understanding and critical thinking skills (Pangesti, Yulianti, & Sugianto, 2017). Lestari et al (2018), also revealed the same thing that the STEM-integrated student worksheet can provide a wider space for students to be active and critical.

Starting from the expected conditions that are not appropriate with reality so that gaps arise, therefore, researchers are interested in developing STEM-based student worksheets to improve student's critical thinking skills in the reaction rate sub-material, concerning indicators of interpretation, analysis, and inference according to Facione (2015). This study uses indicators of interpretation, analysis, and inference because researchers want to know the extent to which the ability to categorize, give meaning and important points of a thing, the ability of students to be able to clarify conclusions from data and relate them to existing concepts and theories and the ability to provide conjectures or hypotheses and conclusions by considering relevant information.

▪ METHOD

The research design is research and development (R&D) until the trial stage in small groups of 15 students of class XI IPA 6 Senior High school Hang Tuah 2 Sidoarjo. The instruments used are study sheets, validation sheets, student response questionnaire sheets, and test sheets for students' knowledge and critical thinking skills.

Data analysis has been done descriptively. There are 3 validators, two Unesa chemistry lecturers, and a Hang Tuah 2 Sidoarjo High School teacher. The data from the validation results were analyzed descriptive quantitatively to calculate the percentage of student worksheet validity, which was developed using a Likert scale with the criteria below.

Table 1. Likert scale

Score	Category
0	Not very good
1	Not good
2	Pretty good
3	Good
4	Very good

(Riduwan, 2016)

After that, calculated by the formula:

Criteria score = Highest score for each item x ∑ item x ∑ validator

After that, to get the percentage value is:

$$(\%) = \frac{Total\ Score}{Criteria\ Scor}\ x\ 100\%$$

The interpretation table is:

Table 2. Rating Percentage

Percentage (%)	Category
0-20	Very invalid
21-40	Invalid
41-60	Quite valid
61-80	Valid
81-100	Very valid

(Riduwan, 2016)

The results can determine the validity of the student worksheet if the percentage value is ≥ 61%. The student response questionnaire was analyzed quantitatively using the Guttman scale with the criteria below.

Table 3. Guttman Scale

Answer	Positive Statement Score	Negative Statement Score
Yes	1	0
No	0	1

(Riduwan, 2016)

The results obtained are calculated by the formula:

$$(\%) = \frac{Total\ Score}{Total\ Respondent}\ x\ 100\%$$

Below is an interpretation table of the percentages obtained:

Table 4. Appraisal Interpretation

Percentage (%)	Category
0-20	Very impractical
21-40	Not practical
41-60	Practical enough
61-80	Practical
81-100	Very practical

(Riduwan, 2016)

Student worksheets can be said to be practical if the value is ≥ 61%.
The results of students' knowledge domain tests are calculated using the formula:

$$\text{Learning outcomes} = \frac{Total\ Score}{Max\ Score}\ x\ 100$$

Then, it was analyzed whether or not there was a difference in the domain of knowledge between before and after the student worksheet was given using the Wilcoxon test. It is said to be complete if a significance value of ≤ 0.05 is obtained (Arikunto, 2011). Meanwhile, to determine the increase in the domain of knowledge, the formula is used:

$$\text{N-gain} = \frac{Postest\ Score - Pretest\ Score}{Maximum\ Score - Pretest\ Score}$$

The N-gain results that have been obtained are then interpreted, with the following criteria.

Table 5. N-Gain Criteria

Score	Criteria
x > 0.7	High
0.3 ≤ x ≥ 0.7	Medium
x < 0.3	Low

(Hake, 2002)

If the N-gain is obtained with a value of 0.3 and above, the student worksheet can be said to be effective. The value of the domain of critical thinking skills is calculated using the formula:

$$\text{Learning outcomes} = \frac{Total\ Score}{Max\ Score}\ x\ 100$$

Then, it was analyzed whether or not there were differences in the critical thinking skill domain between before and after the student worksheet was given using the Wilcoxon test. It is said to be complete if a significance value of ≤ 0.05 is obtained (Arikunto, 2011). Meanwhile, the increase in the value of the critical thinking skill domain has used the formula:

$$\text{N-gain} = \frac{Postest\ Score - Pretest\ Score}{Maximum\ Score - Pretest\ Score}$$

The N-gain results that have been obtained are then interpreted, with the following criteria.

Table 6. N-Gain Criteria

Score	Criteria
x > 0.7	High
0.3 ≤ x ≥ 0.7	Medium
x < 0.3	Low

(Hake, 2002)

If the N-gain is obtained with a value of 0.3 and above, the student worksheet can be said to be effective. The same way is done to find out the results of critical thinking skills on indicators of interpretation, analysis, and inference.

▪ RESULT AND DISCUSSION

The title of this research is " Development of Students Worksheet Based STEM (Science, Technology, Engineering, and Mathematics) to Improve Student Critical Thinking Skill In Reaction Rate" which has the aim of producing appropriate LKPD.

The Validity of Students' Worksheet

The study design is research and development (R&D) until the trial stage in small groups. Here is the explanation:

Potential and Problem Analysis Stage

Potential is something that has added value if it is utilized. However, if it is not utilized there will be a gap between expectations and reality so that it becomes a problem. The identification of potentials and problems is carried out through preliminary studies in the field by conducting interviews with teachers and providing pre-research questionnaires and critical thinking skills questionnaires to students of senior high school Hang Tuah 2 Sidoarjo.

Data Collecting Stage

This stage aims to obtain materials that will be used during the product design stage. This stage needs to be collected includes core and basic competencies, and product requirements.

Product Design Stage

The materials obtained from the data collection stage are designed in such a way as to become a product as a solution to the problems that have been identified in the early stages, so that a STEM-based student worksheet is created, with a design, including covers, procedures for use, core and basic competencies, indicators, learning purpose, and activities which involves the four STEM components, namely Science, Technology, Engineering, and Mathematics.

Design Validation Stage

The student worksheet design produced in the previous step is carried out as an assessment at this step. The assessment involved 3 validators, namely two lecturers of the Department of Chemistry, State University of Surabaya, and a chemistry teacher at Senior High School Hang Tuah 2 Sidoarjo using content and construct validity sheets. Content validity is the condition of an instrument that is evaluated based on the content of the material. Meanwhile, construct validity is the condition of an instrument that is evaluated based on the construct of psychological aspects (Muchlis, 2016). The following are the validation results obtained.

Table 7. Validation Result

Criteria	Percentage	Category
Contents	81.25%	Very valid
Construct	80.69%	Valid

Based on table 7, the validity aspect has been met and is categorized as feasible. Because the average obtained ≥ 61% (Riduwan, 2016). Content validity gets 81.25% (very valid). Content validity has met the BSNP criteria, namely, the material is by core and basic competencies, indicators, and learning purpose (Badan Standar Nasional Pendidikan, 2010), STEM aspects, and compatibility with critical thinking skills (interpretation, analysis, inference).

Construct validity got 80.69% (valid category). This has fulfilled the construct requirements proposed by Darmodjo & Kaligis (1992), including linguistic, writing, and presentation criteria (Hendro & Jeny, 1992).

Design Revision Stage

After the weaknesses of the student worksheet are known, the next step is to revise the student worksheet.

Limited Trial Stage

At this stage, the revised student worksheet was tested limited to a small group of fifteen students of Senior High School Hang Tuah 2 Sidoarjo with different abilities ranging from not smart, moderate, and clever and to determine the domain of knowledge and critical thinking skills of students before giving STEM-based student worksheet through pretest. Then, to find out the difference in the domain of knowledge and the domain of critical thinking skills after the implementation of the STEM-based student worksheet, a posttest was given, and the provision of student response questionnaires.

The Practicality of Students' Worksheet

The practical aspect of the student worksheet is obtained by using a student response questionnaire sheet and the following results.

Table 8. Questionnaire Results

Criteria	Average Percentage	Category
Interest	81.90%	Very interested
Convenience	92.22%	Very easy

Based on table 8, the student worksheet has met the practicality criteria proposed by Sukardi (2011), namely in terms of the interest and convenience of the student worksheet.

The Effectiveness of Students' Worksheet

Aspects of the effectiveness of the student worksheet are known by using a test sheet, including *pretest* and posttest in the domain of knowledge and critical thinking skills of students between before and after the implementation of the STEM-based student worksheet which covers four aspects. Science is the ability to use scientific knowledge, technology is the ability to use technology, engineering is the ability to design experiments, and mathematics is the ability to process data (Afriana, Permanasari, & Fitriani, 2016).

Based on the results of the research by Listyaningrum (2018) in one of the senior high schools in Ponorogo, it shows that more than 50% of students do not understand the real benefits of the chemistry material learned in school in everyday life. A more valuable learning experience is needed in 21st-century learning, thus giving students the ability to be creative in subjects (Yonata, B., Tjahjani, S., & Novita, D., 2018). Based on research conducted by Mulyani, et al 2018, show that students' critical thinking skills are weak, namely, they have not been able to analyze, make assumptions, and determine actions. STEM can help students in solving problems and drawing conclusions from previous learning by applying it through science, technology, engineering, and mathematics (Robert & Cantu, 2012; Lou et al., 2017). STEM-based worksheets can increase students' critical thinking skills, appropriate to the research conducted by Lestari, et al., (2018), and Ramli, et al., (2020), that there is an increase ranging from medium to high categories.

The results of the *pretest* domain of knowledge of students from 15 samples used were not completed with an average value of 38. This was due to the low knowledge of the reaction rate material. However, the implementation of STEM-based worksheets on the material increased significantly. Where 15 students get an average score of 87.

After obtaining the value of the knowledge domain, both pretest and posttest, then tested it with Wilcoxon test by SPSS to know for sure whether the value before the implementation of the STEM-based student worksheet was different from after it was applied. The result of the Wilcoxon test is listed below.

Table 9. The Result of Wilcoxon Test

Test Statistics

	posttest - pretest
Z	-3.423b
asymp. Sig. (2-tailed)	.001

Based on the table, the value is ≤ 0.05. So, the value of the knowledge domain between before the student worksheet is applied is different from after it is applied (Arikunto, 2011). On the other hand, to find out the increase in the domain of knowledge, the n-gain formula was used and it was found that 7 students increased moderately and 8 students increased high.

The test of the domain of critical thinking skills uses 3 indicators, namely interpretation, analysis, and inference proposed by Facione. Interpretation is the ability to categorize, give meaning, and important points of something. The analysis is an ability to identify a relationship between statements, concepts, and questions that aim to provide information, opinions, reasons, and claims. The inference is an ability in terms of providing conjectures or hypotheses and conclusions by considering relevant information (Facione, 2015).

The results of the initial critical thinking skill domain test of 15 samples used were not completed with an average value of 19. However, the implementation of STEM-based worksheets on the material increased significantly. Where 15 students get an average score of 91.

After obtaining the pretest and posttest scores for the critical thinking skill domain, then tested it with Wilcoxon test by SPSS software to know for sure whether the scores before the implementation of the STEM-based worksheet were different from after it was applied. The Wilcoxon test data are listed in table 10 below.

Table 10. The Result of Wilcoxon Test

Test Statistics

	posttestKBK - pretestKBK
Z	-3.411b
asymp. Sig. (2-tailed)	.001

Based on the table, the value is ≤ 0.05, so the value of the domain of critical thinking skills between before the student worksheet is applied is different from after it is applied (Arikunto, 2011).

In addition, the n-gain test was carried out, and it was found that critical thinking skills increased in the high category for the 15 students.

The results of the pretest in the domain of students' critical thinking skills on the interpretation indicators of 15 samples used were not completed and the average value was 22. This was due to the low interpretation ability of students. However, the use of

STEM-based worksheets on the material increased significantly. Where 15 students get an average score of 95.

After obtaining the pretest and posttest scores in the domain of “interpretation” skills, then test it with Wilcoxon test by SPSS software to know for sure whether the scores before the implementation of the STEM-based worksheets were different from those after they were applied. The result of the Wilcoxon test is listed in table 11 below.

Table 11. The Result of Wilcoxon Test

Test Statistics

	posttestinterpretation - pretestinterpretation
Z	-3.415b
asymp. Sig. (2-tailed)	.001

Based on the table, the value is ≤ 0.05, so the domain of "interpretation" skills before the student worksheet is applied is different from after it is applied (Arikunto, 2011).

In addition, to find out the improvement in the domain of "Interpretation" skills, the n-gain formula was used for each and it was found that 15 students increased in the high category.

The results of the pretest in the domain of "analysis" skills on 15 samples were not completed and the average score was 12. This was due to the low "analysis" ability of students. However, the use of STEM-based worksheets on the material increased significantly. Where 15 students get an average score of 79.

After getting the pretest and posttest scores for the “Analysis” skill domain, then test it with Wilcoxon tested by SPSS software to know for sure whether the scores before STEM-based worksheets were implemented were different from after they were applied. The result of the Wilcoxon test is listed below.

Table 12. The Wilcoxon Test

Test Statistics

	posttestanalysis - pretestanalysis
Z	-3.424b
asymp. Sig. (2-tailed)	.001

Based on the table, the value is ≤ 0.05, so the domain of "analysis" skills before applying the student worksheet is different from after it is applied (Arikunto, 2011).

In addition, to find out the improvement in the domain of "Analysis" skill, the n-gain formula was used respectively, and it was found that 2 students increased moderately and 13 students increased high.

The results of the pretest in the domain of "inference" skills on 15 samples were not completed and an average value of 19 was obtained. This was due to the low ability of students' inference. However, the use of STEM-based worksheets on the material increased significantly. Where 15 students get an average value of 92.

After obtaining the pretest and posttest scores for the "Inference" skill domain, then test it with the Wilcoxon test by SPSS to know for sure whether the scores before the implementation of the STEM-based worksheets were different from those after they were applied. The result of the Wilcoxon test is listed in table 13 below.

Table 13. The Result of Wilcoxon Test

Test Statistics

	posttestinference - pretestinference
Z	-3.412b
asymp. Sig. (2-tailed)	.001

Based on the table, the value is ≤ 0.05, so the domain of "inference" skills before the student worksheet is applied is different from after it is applied (Arikunto, 2011).

In addition, to find out the improvement in the domain of "inference" skill, the n-gain formula was used respectively, and it was found that 1 student increased moderately and 14 students increased high.

▪ CONCLUSION

Based on the discussion, it can be concluded that a STEM-based student worksheet is feasible based on three aspects. Aspects of validity include content and construct validity, each getting a very valid and valid category. Aspects of practicality in terms of the results of the questionnaire responses of students get a very practical category. Aspects of effectiveness in terms of the results of the test in the domain of knowledge and critical thinking skills increase in the high category in n-gain score and wilcoxon test.

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