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The Development of Scaffolding Aided Learning Tools Using 5E Learning Cycle Model

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Abstract

Learning tools have important role to promote effective learning process. Available learning tools was still unable to construct good understanding for students especially in acid base topic. The aims of this study were to examine validity and application of tools and to describe improvement of students conceptual understanding before and after tools applied during learning process. Dick and Carey model was applied as research method. Data were collected by means of interview, observation, and test. Data were analyzed through descriptive qualitative analysis. According to data analysis, validity of lesson plan, worksheet, hand book and evaluation tools were 90,95%, 90,59%, 92,16%, and 97,14% respectively which categorized as very valid. The application of learning tools was 92,16% which categorized as very good. The improvement of students conceptual understanding was 0,57 which categorized as average. This research provides learning tools that enhance students conceptual understanding of the concept of acid-base topic.

Keywords: *Development, 5E Learning Cycle, Scaffolding.*

1. Introduction

Students know chemistry for its difficulties due to abstract and complex concepts (Yohana et al., 2018). According to Sunyono & Meristin, (2019), students assume that learning chemistry is complicated. Therefore, students grow antipathy and regard chemistry as a scary subject.

Some research finds that difficulties students face during learning chemistry are the difficulty in understanding Bronsted-Lowry acid-base theory after learning Arrhenius acid-base theory (Kim et al., 2019), difficulty in differentiating between strong and weak acid-base (Yohana et al., 2018), difficulty in writing and balancing sulfuric acid and natrium hydroxide equation, difficulty in determining the concentration of monovalent and bivalent acids (Tri Astuti & Marzuki, 2018). The problems of acid-base concepts have also occurred among students of the chemistry education program of Tanjung pura University. The difficulties are as follows: the difficulty in identifying ionized and hydrolysed species; the difficulty in determining the pH according to conductivity; the difficulty in differentiating strong and weak acids and bases; and the difficulty in determining pH of solutions.

The difficulties that occur among students are caused by lacking understanding of acid-base concepts. Students are found to fail to understand ionization and equilibrium and their connection to acid-base concepts. Furthermore, students are found to have a poor understanding of mol and concentration concepts. The lack of understanding of abstract and algorithmic concepts has led students to have poor learning achievement. According to (Rahmawati et al., 2019) and (Muflihah et al., 2020), conceptual understanding is important due to the ability to retain concepts and create meaningful learning experiences.

According to interviews with lectures of chemistry education program, the course of basic chemistry is still delivered by lecture, question and answer, and experiment methods. According to (Juniarsih, 2015), good learning is not only the transportation of knowledge from teachers to students but rather allowing students to construct their own knowledge. This learning can be realized through constructivism (Muflihah et al., 2020). Through constructivism, students become active and tend to be more prepared for learning (Pratiwi,

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2016). Furthermore, students will obtain knowledge easier if there is a possibility to discuss (Rapitasari et al., 2017).

One of the constructivism based learning models is the 5E learning cycle (Shofiah et al., 2018) and (Imran et al., 2019). The 5E learning cycle consists of 5 phases: engagement, exploration, explanation, elaboration, and evaluation (Sari et al., 2016). 5E learning cycle is designed to promote students learning (Pratiwi, 2016). The 5E learning cycle will involve students in active learning since it is a student's-oriented model (Astriani & Istiqomah, 2016).

5E learning cycle gives students opportunities to construct their knowledge through active learning. The strength of the 5E learning cycle is on students' involvement during learning (Budiman et al., 2019) through active learning, which assimilation, accommodation, and organization of cognitive structure occur (Imran et al., 2019). Some researches show that 5E learning cycle improves students learning achievements (Budiman et al., 2019; Rejeki et al., 2015; Sari et al., 2016), conceptual understanding (Pratiwi, 2016; Sartika, 2018; Sartika & Lestari, 2016), and critical thinking skills (Hartawati et al., 2020; Latifa et al., 2017; Sartika & Lestari, 2016).

The implementation of the 5E learning cycle on chemistry needs learning tools. Therefore, teaching activities occur effectively and efficiently. Since any older learning tools that have already provided tend to place students as receivers, the development is necessary to help students learn. According to Shofiah et al., (2018), teaching tools' development depends on the selection of the learning model. According to Alice & David, (2018), the learning cycle must be the picture of ideal learning.

The use of scaffolding in this study helps students master prerequisite concepts (Pratama & Saregar, 2019). Scaffolding is designed to guide students. Scaffolding can be provided by teachers to guide and promote students learning (Zainuddin et al., 2016; Zamahsari et al., 2019). Scaffolding is also used to explore important and complex phenomena and help students solve their problems (Aprian et al., 2017; Sobirin et al., 2018). Some research shows that scaffolding improves student achievement. Research conducted by (Erlin Eveline et al., 2019) stated that the learning process assisted by IPMLM media with the scaffolding approach can help students complete tasks on the HOTS aspect and improve learning with 21st century learning-based activities. Then the research conducted by (J. C. Y. Sun & Hsu, 2019) stated that he results suggest that several simultaneous types of scaffolding tend to reduce the effectiveness of the scaffolding systems through media-multitasking. Other research was also conducted by (S. W. Sudarman & Linuhung, 2017) stated that Scaffolding learning model can improve students' understanding of concepts in mathematics. The availability of scaffolding aided 5E learning cycle learning tools is expected to help students master acid-base concepts completely by constructing their own knowledge. This study aims to determine the feasibility of the targeted product and to explore the effect of implementing the product on improving student learning achievements.

2. Method

This study was research and development study which adopt Dick, Carey, & Carey steps which are as follows; identifying instructional goals, conducting instructional analysis, analyzing learners and contexts, writing performance objectives, developing assessment instruments, planning the instructional strategy, developing instructional materials, designing and conducting formative assessments and revising instructional materials. Subjects in this study were Lesson plans, worksheets, handbooks, and assessment instruments. These learning tools were tested using one group of pretest-postest design.

The research procedures were as follows: pre-research of student difficulties on acid-base concepts, planning and designing a product using Dick, Carey & Carey research and development model, validating through cooperative discussions, field testing towards seven students of chemistry department who were studying basic chemistry II, and revising learning tools. Data Collection techniques were indirect communications to examine feasibility, observation technique to examine compliance lesson plans, and measurement technique to determine conceptual understanding improvement.

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Instruments used in this study were validation sheets of lesson plans, learning materials, worksheets, and assessment instruments, observation sheets of lesson plan compliance, and achievement tests. The data analysis technique was qualitative descriptive, which steps were as follows: score tabulations, calculating average scores of all components, and interpretation of scores. Reference criteria for learning tool validations were shown in Table 1, and reference criteria for compliance of lesson plans were shown in Table 2.

The improvements of conceptual understanding were determined through qualitative descriptive analysis which steps were as follows: scoring student achievement test, calculating the improvement of student conceptual understanding through normalized gain formula by Hake in (Nissen et al., 2018).

$$g = \frac{(\bar{x}_{post} - \bar{x}_{pre})}{100\% - \bar{x}_{pre}} \quad (1)$$

Note:
g = average score of normalized gain.
$\bar{x}_{post}$ = average score of post test
$\bar{x}_{pre}$ = average score of pre test.

Table 1. Learning tool validation categories

Score (%)	Criteria
80 – 100	Very feasible
66 – 79	Feasible
56 – 65	Moderately feasible
41 – 55	Slightly feasible
0 – 40	Not feasible

(Source: Riduan in (Iswara et al., 2020))

Table 2. Lesson plan compliance categories

Score (%)	Criteria
80 – 100	Excellent
66 – 79	Very good
56 – 65	Good
41 – 55	Fair
0 – 40	Poor

(Source: Riduan in (Iswara et al., 2020))

Normalized gain score criteria were classified into three levels, as shown in Table 3.

Table 3. Normalized gain score classification

Normalized gain	classifications
$g < 0,3$	Poor
$0,3 \leq g < 0,7$	Good
$g \geq 0,7$	Excellent

(Source: Hake in (Nissen et al., 2018))

3. Result and Discussion

Three validators did learn tool validations. The result of lesson plan validation is shown in Table 4.

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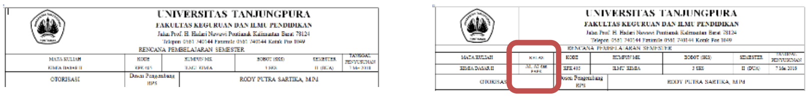
Table 4. The Result of lesson plan validations.

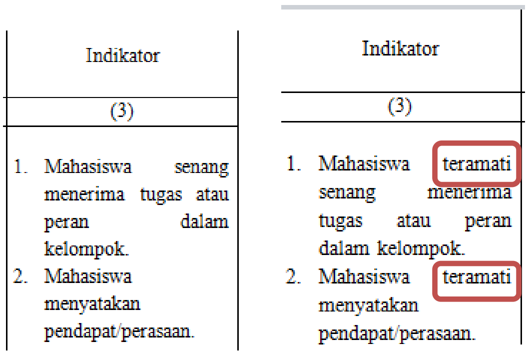
Components	Lesson plan validations		
	Validator 1	Validator 2	Validator 3
Total	68	58	65
Averages	4,86	4,14	4,64
Percentages	97,14	82,86	92,86
Criteria	Very feasible	Very feasible	Very feasible
Validator recommendations	**Applicable with little revision**	**Applicable with little revision**	**Applicable with little revision**

The percentage of average scores from validators is 90,95%, which is categorized as very feasible. According to suggestions from validators during a discussion, there are revisions on lesson plans. They are additions on comment columns, as shown in figure 1. The revision is also located on indicator columns by adding “observed,” as shown in figure 2. The percentage of worksheet validations is 90,59% which is categorized as very feasible (Table 5).



(a) (b)

Figure 1. (a) before, (b) after additions on class of identity column.



(a) (b)

Figure 2. (a) before (b) after addition of “observed” on affective indicators.

The revisions on worksheets one is located in instructional goals, coloring, sentence writing, and placements. The revision on instructional purposes is done by adding “using universal indicators”, as shown in Figure 3.

Table 5. The result of worksheet validations.

Components	Worksheet validations		
	Validator 1	Validator 2	Validator 3
Total	85	68,5	77,5
Averages	5	4,03	4,56
Percentages	100	80,59	91,18
Criteria	Very feasible	Very feasible	Very feasible
Validator recommendations	**Applicable with little revision**	**Applicable with little revision**	**Applicable with little revision**

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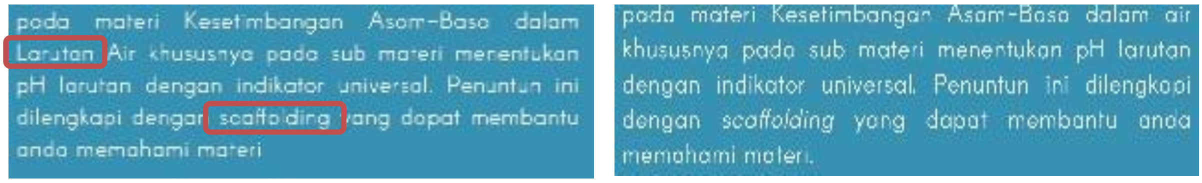
(a) (b)

Figure 3. (a) before (b) after addition of “using universal indicators” on instructional goals.

The revision on coloring is done by erasing white colour on background on related changes of indicator colours, as shown in Figure 4. The revisions of incorrect words/sentences are shown in Figure 5. The placements are to adjust materials on every page, as shown in Figure 6. The revisions on the worksheet two are done by changing colours, especially on the first page, which replaces background colour from black into white, as shown in Figure 7. The revisions on handbooks are in fitness between concepts and indicators, the context of sentences, picture selections, and front cover layout. The result of the handbooks is shown in Table 6.

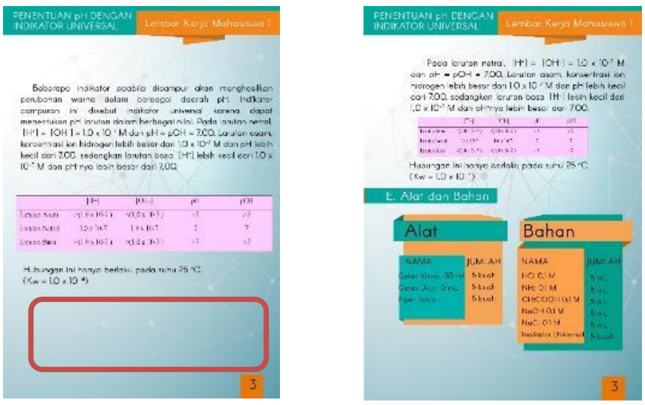
(a) (b)

Figure 4. (a) before (b) after changing of white background colour on reaction equations.



(a) (b)

Figure 5. (a) before (b) after revisions on words/sentences.



(a) (b)

Figure 6. (a) before (b) after changing the placements on worksheet 1 .

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(a) (b)

Figure 7. (a) before, (b) after changing colours on background colour of first page on worksheet 2.

Table 6. The result of handbook validations.

Components	Handbook validations		
	Validator 1	**Validator 2**	**Validator 3**
Total	85	68	82
Averages	5	4	4,82
Percentages	100	80	96,47
Criteria	Very feasible	Very feasible	Very feasible
Validator recommendations	**Applicable with little revision**	**Applicable with little revision**	**Applicable with little revision**

According to Table 6, the average score is 92,16%, which is categorized as very feasible. The revisions are additions of scaffoldings on the topic of weak acid-base pH (Figure 8). The additions of scaffoldings are expected to help students to achieve instructional goals. The revisions on sentence contexts are in the topic of acid-base theories by adding “ions” and “in water”, as shown in Figure 9. The revisions on picture selections are additions of phases of 5E learning cycle in cover layout. These revisions are shown in Figure 10.

(a) (b)

Figure 8. (a) before, (b) after additions of scaffoldings on topic of weak acid base.

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(a) (b)

Figure 9. (a) before and (b) after additions of "ions" and "in aqueous solution".

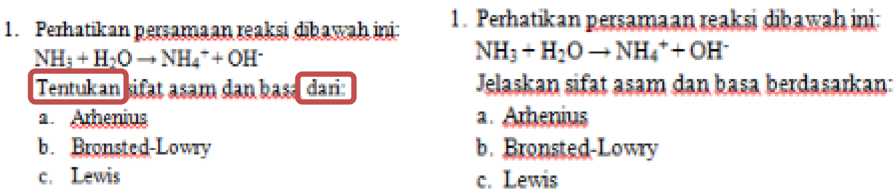
(a) (b)

Figure 10. (a) before, and (b) after additions of phases of 5E learning cycle on cover layout.

Table 7. The result of achievement test validations.

Components	Validations of achievement tests		
	Validator 1	**Validator 2**	**Validator 3**
Total	60	55	60
Averages	5	4,57	5
Percentages	100	91,43	100
Criteria	Very feasible	Very feasible	Very feasible
Validator recommendations	**Applicable with little revision**	**Applicable with little revision**	**Applicable with little revision**

The result of achievement test validations is shown in table 7. The percentage of the average score is 97,14%, which is categorized as very feasible. The revisions are replacements of grammatically incorrect sentences (Figure 11) and unrelated sentences towards indicators and measured behaviors (Figure 12).



(a) (b)

Figure 11. (a) before, and (b) after revisions of sentences on questions thus showing fitness between indicators-questions

After validation processes, the next step is to conduct an initial field test that involves seven students of the chemistry education program of Tanjungpura University. The initial field

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test is done by implementing scaffolding aided learning tools on learning through the 5E learning cycle model. The average score of compliance of lesson plans is 92,16% which is categorized as excellent as shown in Table 8.

Table 8. The measurement of lesson plan compliances during initial field test

Components	Measurement		
	Observer 1	**Observer 2**	**Observer 3**
Total	53	45	57
Averages	4,42	3,75	4,75
Percentages	88,33	75	95
Criteria	**Excellent**	**Good**	**Excellent**

According to observations, there remain obstacles to compliance with lesson plans, especially during the elaboration phase. In this phase, students encounter difficulties completing tasks in worksheet two in the topic of calculations of acetic acid concentrations. Students are confused about using formulas to calculate concentrations. Thus, this phase takes a long time to do. The suggestions are made by simplifying formulas and give an extra example of solving problems as shown in Figure 13

The effectiveness of learning tools can be measured by comparing student achievements before and after treatment given. The improvements of student achievements are shown in Table 6. The average score of improvements after learning with learning tools through scaffolding aided 5E learning cycle model is 0,57 which is categorized as good (Table 9).

3. Salah satu basa kuat $Ca(OH)_2$ biasa digunakan sebagai pengatur pH air limbah dan juga sebagai sumber basa yang harganya relatif murah. Berapakah pH dari larutan $Ca(OH)_2$ 0.01 M!

(a)

3. $Ca(OH)_2$ merupakan satu diantara basa kuat yang biasa digunakan sebagai pengatur pH air limbah dan juga sebagai sumber basa yang harganya relatif murah. Berapakah pH dari larutan $Ca(OH)_2$ 0.01 M!

(b)

Figure 12. (a) before, (b) after revisions of sentences thus showing correct grammar.

(a) (b)

Figure 13. (a) before (b) after simplifying of formulas and additions of problems solving

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Table 9. The improvements of conceptual understanding after treatment given

Codes	*Pretest* Scores	*Posttest* Scores	N-Gain	Improvement criteria
UA1	39,39	61,62	0,37	Good
UA2	17,17	43,43	0,32	Good
UA3	18,18	32,32	0,17	Poor
UA4	44,44	46,46	0,04	Poor
UA5	18,18	27,27	0,11	Poor
UA6	71,72	87,88	0,57	Good
UA7	39,39	63,64	0,40	Good

The improvements of conceptual understanding of acid-base concepts occur to every student (Table 9) after learning with tools developed through scaffolding aided 5E learning cycle model. Learning through the 5E learning cycle model consists of 5 phases: engagement, exploration, explanation, elaboration, and evaluation. According to (Pratiwi, 2016), the 5E learning cycle model guides students to construct their own knowledge. The 5E learning model involves students to explore for constructing knowledge (Sari et al., 2016). According to (Armansyah et al., 2018), the 5E learning cycle model facilitates students actively learning activities such as doing experiments, giving opinions, and asking questions. 5E learning cycle model with discussions and experiments helps to active (Yuliana et al., 2020).

The engagement phase starts by asking definitions of acid and base and explaining the advantages of acids and bases for our daily lives by detecting any existing misconceptions. This phase aims to prepare students to follow the next phase by exploring their previous knowledge (Latifa et al., 2017). Student enthusiasm will increase by adding related phenomena (Putra et al., 2018).

The exploration phase starts by giving opportunities to students to construct knowledge through the experiment of determining the pH of acid-base solutions by the guidance of handbooks and worksheets. According to Latifa et al., (2017), in this phase, students are given opportunities to work in groups to do activities such as doing experiments and reviewing the literature. During this phase, students learn meaningfully, practice, and develop scientific attitudes (Suardana et al., 2018). Students explore their materials to prove their opinions (Putra et al., 2018). According to (Sari et al., 2016), in engagement and exploration phases, students are asked to connect concepts to their daily life contexts to grow interested.

Scaffolding in this study is given during the exploration phase provided in handbooks and worksheet 1 (determining the pH of aqueous solutions). The examples of scaffolding are shown in Figures 8b and 13b. According to (Zamahsari et al., 2019), scaffolding will help students to solve questions by giving them guidance (Zainuddin et al., 2016). Scaffolding will ease students in understanding concepts (Pratama & Saregar, 2019). According to (Sobirin et al., 2018), scaffolding successfully motivates and supports students to plan and implement a strategy to gain knowledge. Scaffolding is guidance for a better learning experience, especially during the early phase of the learning process (Masnia & Zubaidah Amir, 2019).

The implementation of the 5E learning cycle is done in big groups. Therefore, students are able to help others to understand acid-base concepts. According to (Rapitasari et al., 2017), constructivism applies cooperative learning intensively. Thus, students are allowed to discuss complex concepts. Furthermore, students need to learn according to the Zone of Proximal development to interact with them (Aprian et al., 2017).

The explanation phase starts by giving students opportunities to present their work in front of the class to measure their learning achievements. According to Latifa et al., (2017), in this phase, students share their thoughts by their own words. Teachers encourage students to explain concepts by giving evidence (Ilmi et al., 2019). Moreover, during this phase, there occurs in information sharing about concepts (Sari et al., 2016). According to (Kazempour et al., 2020), teacher roles are provided with references and facilitation for discussions.

In the elaboration phase, students conduct advanced experiments by the guidance of worksheet 2 to determine acetic acid concentrations. This activity is carried out to expand concepts found in previous phases. During this phase, students develop concepts and skills in new situations (Latifa et al., 2017). This phase is intended to give students opportunities to apply their knowledge to solve new problems (Suardana et al., 2018). Teachers should provide learning activities that allow authentic experiences (Putra et al., 2018). Connecting concepts with authentic examples of daily life will make concepts useful and meaningful (Sari et al., 2016).

Evaluation is the last phase which starts by asking questions to students to examine their learning achievements. During this phase, teachers assess whether students have successfully achieved instructional goals (Latifa et al., 2017). This phase is intended to give formative evaluations (Suardana et al., 2018). Some research shows that scaffolding improves student achievement. Research conducted by (Erlin Eveline et al., 2019) stated that the learning process assisted by IPMLM media with the scaffolding approach can help students complete tasks on the HOTS aspect and improve learning with 21st century learning-based activities. Then the research conducted by (Jerry Chih Yuan Sun & Hsu, 2019) stated that he results suggest that several simultaneous types of scaffolding tend to reduce the effectiveness of the scaffolding systems through media-multitasking. Other research was also conducted by (Satrio Wicaksono Sudarman & Linuhung, 2017) stated that Scaffolding learning model can improve students' understanding of concepts in mathematics.

This study has developed learning tools (lesson plans, handbooks, worksheets, and instruments of measurements) through the implementation of scaffolding aided 5E learning cycle model, which is categorized as very feasible as shown in Tables 4,5, 6, and 7. Furthermore, the compliance of the lesson plan is categorized as good. The learning tools help students to construct concepts and promote active learning. These achievements are shown from the improvements in student learning achievements, which are categorized as good (Table 9). This result is in line with (Sartika & Ariansyah, 2019) which show the achievements of development through 5E learning cycle. Research conducted by (Murnaka & Yuniarti, 2018) (Murnaka & Yuniarti, 2018) stated that the improvement of math- lemmatical communication ability of students who get learning cycle 5e model is higher than students who get conventional learning.

4. Conclusions and recommendations

In conclusion, the feasibility of lesson plans, worksheets, handbooks, and instruments of assessment is categorized as very feasible. The improvement of conceptual understanding is categorized as good. The recommendations are providing longer duration for guiding intensively during initial field tests (especially in the elaboration phase) because students are found confused in applying and developing concepts.

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