Problem-based learning tools oriented of green chemistry in reaction rate concept

N Fauziah\textsuperscript{1,*}, Y Andayani\textsuperscript{2} and A Hakim\textsuperscript{2}

\textsuperscript{1} Master Science of Education, Universitas Mataram, Jalan Majapahit No. 62, Lombok, Indonesia
\textsuperscript{2} Chemistry Education Study Program, Universitas Mataram, Jalan Majapahit No. 62, Lombok, Indonesia

*imnurulfz@gmail.com

Abstract. The aims of the study to produce and discover the quality of problem-based learning tools oriented to green chemistry in the reaction rate concept. Learning tools consists of the syllabus, lesson plan, student worksheet, modules, and test instruments. This research and development adapted Nieveens model which consisted of four stages: preliminary research, prototyping stage, summative evaluation, and reflection and documentation. The quality of the learning tools developed was measured through the analysis of validity and practicality. Product validity assessment used validation questionnaires distributed to experts, the data obtained were analyzed by using the content validity formula. Practicality used response questionnaires assessed by teachers and students, and the implementation of learning was analyzed by using a percentage of practicality. This study resulted in the average of content validity being 0.67 categorized valid. The practicality percentage of each aspect is 90.87\%, 80.06\%, and 80.56\% categorized highly practical. The concluded that learning tools developed fulfills the criteria for developing quality products that are valid and practical.

1. Introduction
Chemistry learning in schools should facilitate students to obtain 21st-century competencies and skills as well as conservative attitudes towards the environment. Therefore, chemistry learning must be linked to everyday life so that students can connect the knowledge learned with the phenomena that occur in their environment. Environmental problems are a problem that is still found today and is one of the global problems. Therefore, it needs to be used as an approach in chemistry learning.

Taufiq in the research conducted revealed that the interest of students in studying chemistry can be seen directly with learning that is relevant to the environment and everyday life, with the result that to facilitate problem-solving and student activities that connect concepts and the real world, implementation of learning need to be designed through models and learning media that are appropriate to be realized in learning tools [1]. Learning tools represent planning, implementation, and evaluation to realize effective and efficient learning.

Based on the results of preliminary observations conducted at Mataram High School, it shows that most of the learning tools that are applied are still general in nature and less direct students to 21st-century competencies and skills. Most supporting tools such as teaching materials are still using teaching materials sourced from publishers. In addition, the practicum was still guided by tools and materials that
already exist in the laboratory. This results in students only obtaining standard concepts without knowing that there are the same knowledge and concepts that are familiar with the environment and everyday life.

Based on the results of the above observations, it is necessary to develop learning tools using appropriate learning models, methods and concepts. One of learning model that can be applied in chemical learning is problem-based learning. Problem-based learning aims to develop a holistic, student-centered environment [2]. As student-centered learning, problem-based learning is developed to bridge the gap between what was learned in school and its relevance to its application in everyday life [3]. Problem-based learning starts with authentic problems or situations in the real world [4]. Based on this, the competencies and skills demanded in 21st-century education can be realized. In addition to competency and skills, conservative attitudes in learning chemistry are also needed. Referring to one of the main goals in chemistry education, students must be able to develop a basic understanding of the scope, limitations, and consequences of chemical thinking and actions [5].

Chemical thought has been defined as the development and application of chemical knowledge and practice with the main aim of analyzing, synthesizing, and transforming matter for practical purposes [6]. The rise of environmental problems that occur, chemical learning needs to be integrated with environmentally friendly concepts, one of which is the concept of green chemistry [7]. Green chemistry is a movement in the use of chemical processes and products that are more environmentally friendly for pollution prevention and minimizing waste so that it can be used as the main means in designing and realizing sustainable development [8,9]. Green chemistry learning will ensure the creation of a new generation of chemists who have the skills and knowledge to practice environmentally chemistry friendly [10].

Active learning is a very effective way to teach green chemistry because it successfully develops critical thinking about an important aspect in embedding the concept of green chemistry into everyday practice [11,12]. Problem-based learning models by applying scientific concepts and principles including green chemistry can bring students to use their experience and thinking skills to more easily apply the material learned in problem solving in everyday life [13,14].

Therefore, the aim of this research is to develop a problem-based learning tools oriented to green chemistry. The development of this learning tools uses the syntax of problem-based learning by Arends and is oriented to the principles of green chemistry which are limited to six principles which consist of: (1) Preventing the formation of waste; (2) Design of safe materials and products; (3) Use of safe solvents and additives; (4) Use of renewable materials; (5) Use of catalysts; (6) Minimizing the potential for workplace accidents [8]. The learning tools developed is expected to be feasible (valid, practical, and effective) to facilitate students to obtain competencies, skills and attitudes that lead to the 21st century. A good learning tools at least have three important frameworks, those are validity, practicality and effectiveness [15]. In this study discussing the quality of learning tools is limited by aspects of validity and practicality. The practicality of the learning tools developed has been trials at SMAN 3 Mataram.

2. Method

This Research and development (R & D) are developing a product in the form of problem-based learning tools oriented to green chemistry in the reaction rate concept. This research and development adapted Nieveens model which consisted of four stages: preliminary research, prototyping stage, summative evaluation, and reflection and documentation [15].

The first stage, preliminary research, consists of needs and competencies analysis, student analysis, tools analysis, and literature studies. This stage is done through observation and interviews. The second stage, the prototyping stage, is carried out by developing learning tools compiled based on problem-based learning that is oriented to the principles of green chemistry. This tools consists of the syllabus, lesson plan, student worksheet, learning modules, and test instruments. The third stage, summative evaluation, was validated by experts or lecturers who were competent in their fields.

Product validity assessment used validation questionnaires distributed to experts, and the data obtained were analyzed by using the content validity formula. Products that have been declared valid
are used for limited trials related to product practicality. Practicality used response questionnaires assessed by teachers and students, and the implementation of learning was analyzed by using a percentage of practicality. The fourth stage, systematic reflection, and documentation, this stage will be written throughout the study to support the analysis.

3. Result and discussion

The validity aspect according to Nieveen is related to two things [15], namely: (1) the learning tools developed is based on strong theoretical rationality, and (2) there is internal consistency. Practical aspects, according to Nieveen are fulfilled if experts and practitioners state that what is developed can be applied, and what is developed can be applied. Research results can be seen at each stage of development.

The preliminary research stage shows that the implementation of lesson plans is less effective in learning such as learning steps that tend not to be operational and these steps tend to be routine activities so that there are no specifications for learning steps according to the character and development of students. Teaching materials used have disadvantages including not providing models and learning methods that are solid and less directing students in training and developing 21st-century skills.

The second stage, prototyping stage is the product design and development stage which is arranged based on Arends' problem-based learning syntax [16] and is oriented to the principles of green chemistry developed by Anastas and Warner which are limited to six principles [8]. The third stage, summative evaluation where the product produced is then validated by experts. The results of the validation carried out by three experts can be seen in Table 1.

| No. | Assessment Aspects    | Average |
|-----|-----------------------|---------|
| 1   | Syllabus              | 0.78    |
| 2   | Lesson plan           | 0.75    |
| 3   | Student worksheet     | 0.66    |
| 4   | Modules               | 0.60    |
| 5   | Test instruments      | 0.56    |
|     | Overall               | 0.67    |

Based on Table 1 shows the average content validity scores is 0.67 which indicates that the learning tools developed has been feasible to be used. Trials are part of assessing the practicality of learning tools developed. Data on practical results obtained include teacher responses, student responses and implementation of learning. Data from teacher response can be seen in Table 2.

| No. | Assessment aspects    | Average |
|-----|-----------------------|---------|
| 1   | Syllabus              | 92, 50  |
| 2   | Lesson plan           | 87, 79  |
| 3   | Student worksheet     | 89, 59  |
| 4   | Module                | 91, 12  |
| 5   | Test instruments      | 93, 34  |
|     | Overall               | 90, 87  |

Table 1. Validation results of learning tools by the experts.

Table 2. The practicality results of learning tools based on the teacher’s response.
Based on Table 2 above shows that the average percentage of the practicality of teacher responses scores 90, 87% which shows that learning tools are very practical to be applied in learning. Other practical data was obtained from the response of 15 students. The results of the assessment can be seen in Table 3.

### Table 3. The practicality result of learning tools based on the student’s responses.

| No. | Indicator of assessment | Average %  |
|-----|-------------------------|------------|
| 1   | Motivation              | 80.44      |
| 2   | Learning                | 79.44      |
| 3   | Material                | 76.43      |
| 4   | Practicum               | 82.46      |
| 5   | Readability             | 81.56      |
|     | Overall                 | 80.06      |
|     | Category                | Very Practical |

Student response data shows students are very interested in practicum activities carried out with a percentage on average practicality of 82.46%. The green chemistry practical approach presented in the module and student worksheet which is then implemented through learning attracts students' attention because the approach taken is different from the previous (conventional) approach. Students are interested in replacing conventional practicum activities with green chemistry practicum because through this student can get a real appreciation for solving problems in their environment and the context of appropriate environmental education to develop a more positive environmental value orientation [17].

Based on the data in Table 3, it shows high motivation towards learning using the developer tools. Through problem-based learning, students are cognitively involved in solving problems, developing evidence-based explanations, and communicating ideas so students will be motivated in learning [18]. The results also show that with green chemistry-based learning it allows positive changes to students' attitudes to studying chemistry, and is more motivated to study chemistry [19]. The concept of green chemistry is not only an addition but also carries a function of motivation, hence green chemistry involves the cognitive domain and also increases the effective side by increasing motivation [20]. Furthermore, the data from the implementation of learning can be seen in table 4.

### Table 4. The practicality result of learning tools based on the implementation of learning.

| No. | Meeting       | Average %  |
|-----|---------------|------------|
| 1   | Lesson plan 1 | 83.33      |
| 2   | Lesson plan 2 | 79.17      |
| 3   | Lesson plan 3 | 79.17      |
|     | Average       | 80.56      |
|     | Criteria      | Very practical |

This shows that green chemistry-oriented problem-based learning can be concluded to be very practical to be applied to learning with a total percent average practicality is 80.56%. Some of the activities that are not implemented are used as homework assignments such as compiling reports and solving questions in the evaluation section.

In the third stage also carried out revisions and improvements based on suggestions and comments from experts, teachers, and students. Improved suggestions and comments are shown in Table 5.
Table 5. Suggestions and comments.

| No. | Assessment | Comments and Suggestions |
|-----|------------|--------------------------|
| 1.  | Validator  | Material descriptions in lesson plans do not need to be specifically presented  
      |             | Background on module cover is replaced with images that can be guaranteed originality  
      |             | Data needs to be searched which are presented in the form of current, interesting, and orientation in everyday life  
      |             | The concept of green chemistry is less precise |
| 2.  | Teacher    | Time allocation needs to be considered in each learning activity  
      |             | The Material in the order sub-reaction order needs to be added |
| 3.  | Students   | Difficulties in answering questions in the module, because it requires a lot of explanations in response |

Based on the suggestions in Table 5 improvements have been made. The physical forms of the modules that have been developed before and after revision can be seen in the following Figure 1 and Figure 2.

![Figure 1. Cover modules before revision.](image1)

![Figure 2. Cover modules after revision.](image2)

The data and information on the modules have been adapted to daily life, such as the relationship between the rate of reaction with fruit ripening, the effect of concentration on the purifying material of contaminated water in the Karang Jangkok River, Mataram, NTB, and other information.

The fourth stage, systematic reflection, and documentation were carried out the documentation at the end of each procedure at each stage of the development. Furthermore, the specification of the design principle is carried out and articulates its relationship with the predetermined frame of mind so as to produce final conclusions on the quality of the learning tools developed.

4. Conclusion

Based on the results of the research obtained, it can be concluded that the learning tools developed has fulfilled the development criteria which are valid and practical. This shows that the tools developed can be implemented in schools and can be conducted on a large scale trial to determine the effect of learning tools on companion variables.
Acknowledgments
The authors would like to thank a team of experts (validators) who have provided assessments, suggestions, and input in this development research and also SMAN 3 Mataram, which has given permission to carry out this research.

References
[1] Taufiq M, Amalia A V, Parmin P and Leviana A 2016 Design of science mobile learning of eclipse phenomena with conservation insight android-based app inventor 2. *JPII* 5 291-298.
[2] Alwi S R W, Yusof K M, Hashim H and Zainon Z 2012 Sustainability education for first year engineering students using cooperative problem based learning. *Procedia Social and Behavioral Sciences.* 56 52-58
[3] Wijnia L L 2014 Motivation and Achievement in Problem-Based Learning: The Role of Interest, Tutors, and Self-directed Study (Rotterdam, the Netherlands: Erasmus University Rotterdam)
[4] Webb A and Moallem M 2016 Feedback and feed-forward for promoting problem-based learning in online learning environments. *MJLI.* 13 1-41
[5] Karpudewan M and Meng C K 2017 The effects of classroom learning environment and laboratory learning environment on the attitude towards learning science in the 21st-century science lessons. *MJLI.*) 25-45
[6] Sjöström J and Talanquer V 2018 co-reflexive chemical thinking and action *Current Opinion in Green and Sustainable Chemistry.* 13 16-20
[7] Sevian H and Talanquer V 2014 Rethinking chemistry: a learning progression on chemical thinking *CERP.* 15 10-23
[8] Anastas P T and Warner J C 1998 *Green chemistry: Theory and Practice* (Oxford: Oxford University Press)
[9] Lokteva E 2018 How to motivate students to use green chemistry approaches in everyday research work: Lomonosov Moscow State University, Russia. *Current Opinion in Green and Sustainable Chemistry.* 13 81-85
[10] Elks I and Rauch F 2012 Sustainable development and green chemistry in chemistry education. *CERP.* 13 57-58
[11] Summerton L, Hurst G A and Clark J H 2018 Facilitating active learning within green chemistry. *Current Opinion in Green and Sustainable Chemistry.* 13 56-60
[12] Hjeresen D L, Boese J M and Schutt D L 2000 Green chemistry and education. *J. Chem. Educ.* 77 1543
[13] Gunter T, Akkuzu N and Alpat S 2017 Understanding ‘green chemistry’ and ‘sustainability’: an example of problem-based learning. *Res in Sci & Technol Edu.* 35 500-520
[14] Yoon H, Woo A J, Treagust D and Chandrasegaran A L 2014 The efficacy of problem- based learning in an analytical laboratory course for pre-service chemistry teachers. *Int. J. of Sci Educ.* 36 79-102
[15] Plomp T and Nieveen N 2013 *Educational Design Research, Part A: An Introduction* (Enschede, Netherlands: Netherlands Institute for Curriculum Development (SLO))
[16] Arends R I 2012 *Learning to Teach. Ninth Edition* (New York: McGraw-Hill)
[17] Anastas P T and Beach E S 2009 *Changing the course of chemistry* (Washington, DC: American Chemical Society) pp 1-18
[18] Wahyuningsih A S Poedjiastoeti S and Suyono S 2017 The effect of green chemistry laboratory learning on pre-service chemistry teachers’ environmental value orientations and creative thinking skill. *JPPS.* 5 848-858
[19] Sprokken-Smith R and Harland T 2009 Learning to teach with problem-based learning. *Active Learn Educ.* 10 138-153
[20] Kolopajlo L 2017 Green Chemistry Pedagogy. *Phys. Sci. Rev.* 2