Development of Green Chemistry Learning Book to Improve Students’ Learning Outcomes

I D A Sri Wulan¹, I W Redhana², and P B Adnyana³

¹,²,³Universitas Pendidikan Ganesha, Bali, Jalan Udayana 11 Singaraja Bali Indonesia - 81116

E-mail: wulananggadewi95@gmail.com

Abstract. This study aimed to produce a green chemistry learning book to improve students’ learning outcome. Type of study was a research and development by adopting the Thiagarajan model. The stages of this study included (1) define phase including front-end analysis, students’ analysis, task analysis, concept analysis, and specifying instructional objective, (2) design phase including preparation of syllabus, lesson plan and the green chemistry learning, (3) develop stage including testing of validity, practicality and effectivity of the green chemistry learning book. The data in this study were analyzed using descriptive statistical analysis techniques. Data analysis result obtained in this study were need analysis data of teacher and student, the characteristics of learning book, validity, practicality and effectiveness data of learning book. The results of the study indicated that (1) the characteristics of the learning book which were developed included the presentation of the dangers of synthetic chemicals, the prevention of the use of synthetic chemicals, and the substitution of synthetic chemicals with environmentally friendly materials, (2) learning book developed had valid, practical and effective categories. The learning book could be applied to improve students’ learning outcome.

Keywords : Green Chemistry Book, Learning Chemistry, Students’ Learning Outcome.

1. Introduction
The development of the 21st century is remarked by the advanced and rapid science and technology that demands the quality of human resources. Education plays a very important role in improving the quality of human resources so that the quality of education must be prioritized and improved. Educators must have creativity in combining the right methods, strategies, and teaching approaches so that learning can run effectively and efficiently [1]. As an alternative, the teacher can replace the learning model by using interactive media, developing students’ worksheet, modules and developing learning books.

Learning books are one of the learning media that play a role in improving student understanding and learning outcomes. Learning books is used as resources in chemistry teaching and learning process that can accommodate students with varying levels of understanding. Chemistry teaching and learning process is currently challenged to address sustainable development in society known as green
chemistry strategies [2]. Green chemistry focused in the application of chemical principles in designing, using, and producing chemicals to reduce the use or production of hazardous substances to prevent environmental pollution and negative health impacts [1]. Considering the concept and approach of green chemistry as an alternative in preventing pollution due to chemicals that can damage the environment and health, it is necessary to consider applying the idea of green chemistry in schools. It also can increase knowledge of students to care about the environment for sustainable development.

Based on observation, chemistry experiment in several schools still applying conventional experiment that used hazardous substances or synthetic chemicals. The waste that is produced from conventional experiment in schools also affects the destruction of natural environment even though a small percentage. Therefore, it needs to replace synthetic chemicals with environmentally friendly chemicals and reduce the quantity of chemicals into micro scale for hazardous chemicals that cannot be replaced with environmentally materials. It aims to provide students’ awareness and students’ understanding about the information of dangerous chemicals, how to prevent the use of synthetic chemicals as well as information how to handle if exposed to chemicals. The advantages of replacing chemicals with environmentally friendly materials are low cost, guaranteed safety and ease of use materials.

The application of green chemistry in the teaching learning process can be applied in the form of learning book. Peratiwi et al. (2014) state that chemistry experiment based on environmentally firendly material is very good and can be applied to students [3]. Then research conducted by Nuraibaity (2011) shows that the green chemistry approach becomes an innovation in chemistry learning with an environmental perspective [1]. Furthermore, research conducted by Shamugathan and Karpuwedan (2017) shows the findings that students who are taught about green chemistry through experiments become more concerned about the environment [4]. Then the results of research conducted by Redhana and Merta (2017) show that the green chemistry practicum method is more effective than conventional practicum methods in improving chemistry learning outcomes [5]. Based on the problems described above, researchers are interested to develop green chemistry learning books to improve student learning outcomes. In addition, the green chemistry learning book developed also aims to increase the awareness of teachers and students to care more for the environment by using environmentally friendly materials as well as reducing the use of hazardous chemicals.

2. Method
Type of study was a research and development adopting the Thiagarajan model that consists of 4 main stages or phases, that are define, design, development and disseminate. However, this research did not carry out the deployment stage due to time and cost limitations. This research was conducted at SMA Negeri 3 Denpasar semester II of the 2018/2019 school year in class XI MIPA 6, with 33 students. The research procedure starts from the stages: (1) define phase including front-end analysis, students’ analysis, task analysis, concept analysis, and specifying instructional objectives, (2) design phase including preparation of syllabus, lesson plan and the green chemistry learning, (3) develop stage including testing of validity, practicality and effectivy of the green chemistry learning book. The instruments used in this study were questionnaires, learning book assessment sheets and tests. Test that is used is learning achievement test that already valid and reliable. The data in this study were analyzed using descriptive statistical analysis techniques. Data analysis result obtained in this study were need analysis data of teacher and student, the characteristics of learning book, validity, practicality and effectiveness data of learning book.

3. Result and Discussion
The study was conducted through research and development that consists of three stages or phase that are define, design and develop. In the define stage, obtained (1) need analysis data of teacher and student by distributing questionnaires about green chemistry learning book to 10 chemistry teachers
and 60 students in Denpasar. The result of teachers’ need analysis data state that 100% teacher thought green chemistry learning book need to developed.

The result of students’ need analysis data showed that chemistry learning book of student not yet inserted the concept of green chemistry. (2) Students’ analysis data in the form of learning style showed that 58.33% of students tend to visual learning styles. Students’ analysis data in the form of motivation to learn showed that the level of student motivation of 76.53% is classified as sufficient category. Then the students’ learning ability data can be seen from the achievement of the students’ chemistry tests. Students’ ability data can be seen in Figure 1. (3) Task analysis data given by the teacher to students on the topic of colloids includes the task of making colloidal projects and the task of making papers. (4) Concept analysis data on the topic of colloids shows 42.86% is a type of concept based on principles. (5) The specifications of learning objectives are formulated in accordance with core competencies and basic competencies which later become the basis for designing learning tools which are then integrated into the material in green chemistry learning books.

![Figure 1. The Students’ Average Data of Chemistry Result](image)

In the design stage, the design of learning devices and the design of green chemistry learning book are obtained. In the development stage, the stages of product validity and field testing are carried out in the form of practicality and effectiveness data. Validity test is carried out to determine the validity of learning book content and media. The validation of the learning book was conducted by two chemistry education lectures (experts) and two chemistry teacher in Denpasar. The validity result of learning books was 87.10% that means the result of learning book in the valid category.

The readability test phases conducted for nine students of class XII showed that the green chemistry learning book developed were good about 61.11%. The field test phase consists of practicality and effectiveness tests. The practicality phase of the learning book was carried out by three chemistry teachers and 33 students. The practicality test results showed the practicality level of learning books of 81.50% classified into practical categories. The effectiveness test phase was carried out on 33 students. Data on the effectiveness of the test results is the test data of the pretest and posttest learning outcomes of students who learn by using learning books that have been developed. Data were analyzed using one sample proportion test and supported by normalized gain score and posttest results tested using one sample proportion test compared with KKM chemistry subjects by 70 and classical completeness by 85% (0.85). Summary of student pretest and posttest data are presented in the following Table 1.

| Table 1. Summary of Students’ pretest and posttest data |
|---------------------------------------------------------|
| **Pretest Score** | **Posttest Score** |
|               |               |

3
| Highest Score | 70 | 90 |
| Lowest Score  | 46 | 70 |
| Average       | 52.18 | 78.18 |
| Standard Deviation | 7.32 | 6.43 |
| Normalized Gain score | 0.54 |

In one sample proportion test, if the significance value < 0.05 then, the null hypothesis (H₀) is accepted and the alternative hypothesis (Hₐ) is rejected, and vice versa if the significance value > 0.05 then, the null hypothesis (H₀) is rejected and the alternative hypothesis (Hₐ) received. The hypothesis tested in this study is as follows.

H₀: proportion of students who score less than or equal to 70
Hₐ: proportion of students who score more than 70

A summary of the test results for the proportion of one sample is presented in Table 2.

**Table 2. Summary of Proportion Test Results for One Sample**

| Category          | N  | Observed Prop. | Test Prop. | Asymp. Sig. (1-tailed) |
|-------------------|----|----------------|------------|------------------------|
| Result of Learning |    |                |            |                        |
| Group 1 <= 70     | 4  | .12            | .15        | .036ab                 |
| Group 2 > 70      | 29 | .88            |            |                        |
| Total             | 33 | 1.00           |            |                        |

The results of this study concluded that (1) the results of the validation of this learning book by validators experts and practitioners classified as valid with a learning book validity level of 87.10%, (2) the results of practicality tests by teachers and students who use this learning book are classified as practical with the level practicality of learning books 81.50%, (3) the results of the effectiveness of learning books using the test of the proportion of one sample is this learning book is effective in improving student learning outcomes that exceed classical completeness by 0.88 and the gain score obtained is in the medium category that means green chemistry learning book can increase students’ learning achievement and (4) Characteristics of green chemistry learning books developed are to provide three studies of information or aspects that are presented in chemical info containing aspects of the dangers of synthetic chemicals, prevention of the use of synthetic chemicals and replacement of synthetic chemicals. Characteristics of green chemistry learning books can be seen in Figure 2. This learning book is also provided summaries, practical activities, and practice exercises.
Figure 2. The Characteristics of Green Chemistry Learning Books

This developmental research is supported by relevant research results including, the research of Baun et al. (2006) and Burmeister and Eilks (2012) showed that the green chemistry curriculum is used in learning to emphasize student-centered activities including material that can be found in the environment of school [6][7]. Other research results reported by Nurbaity (2011) showed that experiment activities in laboratoriy oriented to the principles of green chemistry can reduce, eliminate and replace the use of toxic and hazardous chemicals [1]. Then, the research of Heaton et al. (2006), Karpuwedan et al. (2011), and Juntunen & Aksela (2014) showed that student learning outcomes taught the concept of green chemistry increased and were more concerned about the environment [8][9][10].

Sudarmin's research (2013) showed that prospective chemistry teachers understand the use of inappropriate chemicals and their effects on the environment [11]. Peratiwi et al. (2014) reported that environmentally friendly chemistry lab manuals were categorized very well and could be applied to students [3]. Research conducted by Karpuwedan et al. (2016) shows that the ability of students who are given learning to argue in the concepts of acids and bases inserted by the concept of green chemistry is at a moderate level [12]. Then Redhana and Merta's research (2017) state that learning with green chemistry experiment methods is more effective than conventional chemical practicum methods in improving student learning outcomes [5].

4. Conclusion

Based on the results of the study and discussion can be concluded as follows. The results of the validity of this learning book by validators experts and practitioners classified as valid with a learning book validity level of 87.10%. The results of practicality tests by teachers and students who use this learning book are classified as practical with the level practicality of learning books 81.50%. The results of the effectiveness of learning books using the test of the proportion of one sample is 0.88 that means learning book is effective in improving student learning outcomes the gain score obtained is in the medium category. The characteristics of green chemistry learning books developed are to provide three information or aspects that are presented in chemical info on learning books containing aspects of the dangers of synthetic chemicals, prevention of the use of synthetic chemicals and replacement of synthetic chemicals. This book is also provided with summaries, practical activities, and practice exercises.

Based on the results of this study it can be suggested that green chemistry learning book developed can be used as a tool to support the teaching and learning process in class.

References

[1] Nurbaity. 2011. Pendekatan Green Chemistry Suatu Inovasi dalam Pembelajaran Kimia Berwawasan Lingkungan. Jurnal Riset Pendidikan Kimia, 1(1), 13-21
[2] Eilks, I. & Rauch, F. 2012. Sustainable Development and Green Chemistry in Chemistry Educatio. Chemistry Education Research and Practice, 13, 57–58
[3] Peratiwi, K.A., Redhana, I.W., & Maryam, S. 2014. Buku Pedoman Praktikum Kimia Ramah Lingkungan untuk Pembelajaran Kimia SMA. Jurnal Pendidikan Kimia, 2(1), 66-75.
[4] Shamuganathan, S. & Karpuwedan, M. 2017. Science writing heuristics embedded in green chemistry: a tool to nurture environmental literacy among pre-university students. Chemistry Education Research and Practice, 18, 386-396
[5] Redhana, I.W. & Merta, L.M. 2017. Green Chemistry Practicum To Improve Student Learning Outcomes Of Reaction Rate Topic. *Cakrawala Pendidikan*, 3, 382-403.

[6] Braun, B., Charney, R., Clarens, A., Farrugia, J., Kitchens, C., Lisowski, C., Naistat, D. & O’Neil, A. 2006. Completing Our Education: Green Chemistry in the Curriculum. *Journal of Chemical Education*, 83(8), 1126-1129.

[7] Burmeister, M. & Eilks, I. 2012. An Example of Learning about Plastics and their Evaluation as A Contribution to Education for Sustainable Development in Secondary School Chemistry Teaching. *Chemistry Education Research and Practice*, 13, 93–102.

[8] Heaton, A., Hodgson, S., Overton, T., & Powell, R. 2006. The challenge to develop CFC (chlorofluorocarbon) replacements: a problem based learning case study in green chemistry. *Chemistry Education Research and Practice*, 7(4), 280-287.

[9] Karpuwedan, M., Ismail, Z. & Roth, W.M. 2011. Ensuring sustainability of tomorrow through green chemistry integrated with sustainable development concepts (SDCs). *Chemistry Education Research and Practice*, 13, 120–127.

[10] Juntunen, M.K. & Aksela, M.K. 2014. Improving students’ argumentation skills through a product life-cycle analysis project in chemistry education. *Chemistry Education Research and Practice*, 15, 639-649.

[11] Sudarmin. 2013. Kemampuan Generik Sains Kesadaran tentang Skala sebagai Wahana Mengembangkan Praktikum Kimia Organik berbasis Green Chemistry. *Jurnal Pendidikan dan Pembelajaran*, 2(1), 18-24.

[12] Karpuwedan, M., Roth, W.M., & Sinniah, D. 2016. The Role of Green Chemistry Activities in Fostering Secondary School students’ understanding of acid base concepts and argumentation skills. *Chemistry Education Research and Practice*, 17, 893-901.