

Integration Green Chemistry Approach in Teacher Education Program for Developing Awareness of Environmental Sustainability

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Abstract

The research portrays the integration of green chemistry approach in teacher education program to develop pre-service and in-service teachers' awareness of environmental sustainability. The research was conducted for pre-service (undergraduate) and in-service teachers (postgraduate) education in chemistry classroom. The Green Chemistry approach with 12 principles was applied in education in order to engage students' awareness of environmental sustainability within their future and current role as teachers. A qualitative approach was employed in this research and involved interviews, observations and the use of reflective journals. This research integrated the green chemistry values and principles into the curricula, developed teaching resources and laboratory experiments. The results of the study showed that the pre-service and in-service teachers become aware of environmental problems and to think about their future and current role as teachers. They started to reflect on the values and principles of green chemistry that can be implemented in chemistry classrooms. During laboratory experiments, by reducing the use of chemical substances, the pre-service teachers actively engaged in environmental sustainability in the university. The study also found that the soft skills of collaboration with others, communication and argumentation skills, then creative and critical thinking skills were developed. Thus, the research provides an opportunity to empower pre-service and in-service teachers in strengthening human beliefs and attitudes which are essential in sustaining the environment.

Keywords: *Green Chemistry, Environmental Sustainability, Pre-service Teachers, In-service Teachers, Teacher Education*

1. Introduction

Education

has a strategic role to raise the awareness. This is in accordance with Gadotti (2003) opinion, sustainability of environment depends on the awareness and the awareness depends on the education. So, the earth not only to exploit its natural resources but its conservation must be maintained. According to Morris (2002), it is difficult to shift our perspective from earth as a tool for being exploited to being sustaining. Education is a process that can change the perspective of each individual, thus education plays an important role in increasing every individual awareness in maintaining the environment preservation by integrating environmental sustainability (environment sustainability) in the curriculum. Furthermore Morris (2002) stated that consciousness is good starting point for reconceptualise the cognition which is not separated from the nature of environment and educators should re-imagine about sustainability education might be. Finally, the students not only have the awareness to protect the environment, but also play an active role.

Teachers play an important role in generating environmental sustainability by empowering the younger generations in strengthening human beliefs and attitudes which are essential in sustaining the environment. Claims about benefits of engaging students in environmental education programs are many and widespread (Gough, 1997) including improvement in academic achievement, problem solving, critical thinking, and co-operative learning skills and an increased motivation to learn. In

chemistry teacher education program, it is important to empower the students' teachers to participate reducing and preventing the negative impacts of dangerous chemical substances. Therefore, integrating the green chemistry approach within teaching could be powerful tools to encourage students not only to be aware of the environmental problems, but also to be active participants for better environment in the future.

The chemical substances cause several environmental problems such as water, air, and soil pollutions which have given significant negative effects for the environment, human health, and the quality of life. Toxic waste is harmful material that often is found in chemical substances that can cause death or injury to living organisms. Moreover, industries discharge their waste that contains many hazardous wastes to river. That can cause long-term risk to health and environment. The polluted river can lead to the death and disappearance of many amphibians. Moreover, the greenhouse effect and global warming are the global issue of environment which leads to the increase in temperature throughout the world. The main cause of global warming is due to increasing a large amount of gases which are chemical substances which trap in the atmosphere. The major gases which contribute significantly to global warming are carbon dioxide (CO₂) and chlorofluorocarbons (CFC_s). The former is resulted from burning forests and fossil fuels, such as oil and coal, and the latter from refrigerators and air conditioning. Furthermore, the conditions of environment will be getting worst, if the people are doing nothing. The entire world try to find out the solutions and many suggestions to solve this problem, but without the people' awareness of their environmental problem, the suggestions seem to be useless.

Green chemistry is the strategy to minimize the impacts of chemical substances into human and environment risks. Green chemistry can be applied in the laboratory by preventing and minimizing the waste and using safer chemical substances. In teaching and learning, green chemistry can be applied as world view for environment sustainability. It can be integrated in the curriculum and teaching resources. Green chemistry can play an integral role in moving society toward a more positive, sustainable direction (Klingshirn, & Spessard, 2009). In Addition The effort to integrate green chemistry to the curriculum teacher is still consistent with the needs of making education focused on sustainable development, influenced by motivations and attitudes (Karpudewan, Ismail & Roth, 2012; Karpudewan, Ismail & Mohamed, 2009). Green chemistry have 12 basic principles can give students with positive messages for environmental sustainability, so as to improve knowledge and increase awareness to protect the environment and improve of student awareness towards environmental sustainability and environmental preservation.

This study focused the integration of green chemistry approach in teacher education program to develop pre-service and in-service teachers' awareness of environmental sustainability both in undergraduate and postgraduate study. As chemistry teacher educators, we taught both content and pedagogy. In this study, we integrated green chemistry in Basic Chemistry Course and Issues in Chemistry Education. This study was conducted using qualitative research methodologies to explore students learning experiences in understanding their involvement and active participation the environment sustainability.

2. Literature Review

2.1. Green Chemistry

Green chemistry is one of the strategies that can be done for environmental sustainability (sustainability environment). Doxsee and Huchison (2004), green chemistry is new method to decrease chemical hazards, besides to produce a product with more efficient and more economical ways. Green chemistry is an essential part in a comprehensive program to protect human health and the environment. Meanwhile, Anastas and Williamson (1996) defines green chemistry is the use of techniques and methods chemically to reduce or eliminate the basic material usage, products, by

products, solvents, reagents that are harmful to human health or the environment. According to Anastas, and Williamson, (1996, p. 1), Green Chemistry is "an approach to synthesis, processing, and the use of chemicals that Reduces the risks to humans and the environment". Green Chemistry has 12 principles, namely: "(1) prevention, (2) atom economy, (3) less hazardous chemical syntheses, (4) designing safer chemicals, (5) safer solvents and auxiliaries, (6) design for energy efficiency, (7) use of renewable feedstock, (8) reduce derivatives, (9) Catalysis, (10) design for degradation, (11) real-time analysis for pollution prevention, (12) inherently safer chemistry for accident prevention".

Green Chemistry is not only implemented in the laboratory and the chemical industry, but also applied in education. Development of Green Chemistry in chemical education has the ultimate goal of raising awareness (awareness) and the active participation (empowerment) students as teachers and prospective teachers of chemistry to apply the basic concepts of Green Chemistry as part of the solution to environmental problems, especially those caused by the use of materials chemistry. Based on the basic concept of green chemistry are several definitions of the above, the green chemistry is a strategy or method for reducing the impact of chemicals hazardous to human health and the environment. Therefore, the concept of green chemistry is important to be applied by integrating the learning process called Green Chemistry Education.

According to Collins (2015) Green chemistry has been serving as the first dynamic laboratory for working through the intra- and inter-disciplinary and cross-sector challenges associated with the transformation of a physical science to sustainability-promoting consciousness and action. Therefore, the green chemistry experience could be of value to other fields. According to Haack, Hutchison, Kirchof, and Levy (2005), green chemistry provides the opportunities for innovation in the curriculum integration and engaging students into environmental awareness. Integrating 12 principles of green chemistry into class material will give essential basic concept of green approaches both theory and practical (Braun,et al, 2006). Based on that theory, meaning the integration of green chemistry in chemistry can be made at the chemistry curriculum, applied in the learning process both in theory and practicum, and green chemistry as a subject in itself.

In relation to environmental sustainability, green chemistry is one approach which focuses on giving contribution for the sustainability environmental throughout minimizing the using of chemical substances. The example of this approach in the chemistry laboratories could be applying small quantity of chemical substances, substitution of dangerous chemical substances, and recycling the waste. Therefore, in laboratory, green chemistry approach will help to reduce waste, effective practicum in laboratory, support safety management, and reduce the cost because of using less quantity of chemical substances.

2.2. Environmental Sustainability

Sustainable environments are important, because we realise that humans cannot be separated from the universe. Meanwhile, education is a fundamental part of the environmental sustainability process because education is "the building block for a society to enrich its human capital" (Munier, 2005, p.132). Thus, education can be a meaningful tool in empowering people to engage with environmental sustainability. Various terms have been used to describe the role of education in environmental sustainability. For example, sustainability education shares similar goals and objectives with environmental education (Chansomsak & Vale, 2008). Environmental education was proposed in 1975 in Belgrade in a UNESCO meeting (Gough, 1997). The term sustainability education emerged after 1992 in the Nations Conference on Environment and Development (UNCED) in Rio de Janeiro (Chansomsak & Vale, 2008). According to Gough (1997) and Fien and Maclean (2000), environmental education should stimulate individual responsibility and action on both physical and aesthetic qualities of the environment.

Sustainability environment and environmental education have a common ultimate goal to be achieved, namely the active role each individu to preserve (Chansomsak & Vale, 2008). According to

Chansomsak and Vale (2008) as previously noted, there are three forms sustainability education: education about sustainability, education for sustainability, and education as sustainability. Education about sustainability focus on developing the content of the material provided, education for sustainability focus on the purpose of the material, while education as sustainability focused on empowerment and action.

Sustainability environment is a complex system that is influenced by multidimensional factors, so that the solution of environmental problems to be solved in an integrated manner, including through educators. Educators should be aware that sustainability education is a holistic process, not only limited to integrate environmental topics in the curriculum, but how to achieve the ultimate goal of environmental education is students' empowerment as a form of education as sustainability. Blewitt (2006) stated it is important to empower teachers and students to take action in their everyday practice for a better future for the environment. Environmental sustainability is not only the responsibility of developed countries and governments, but is the responsibility of all humans. Therefore, education should also play an important role in environmental sustainability.

3. Research Methodology

The research aimed to implement a green chemistry approach in or to develop students' awareness of environmental sustainability. The research was integrated in a Basic Chemistry Course for undergraduate students and Issues in Chemical Education Course for Postgraduate students in teacher education program for one semester. The Green Chemistry approach with 12 principles was applied in education in order to engage students' awareness of environmental sustainability. A qualitative approach was employed in this research and involved interviews, observations and reflective journals. Characteristics of this research focuses on the deep understanding of the research context and students' teachers learning experiences.

4. Results and Discussion

4.1. Integration Green Chemistry Approach

Green Chemistry integration in the chemistry courses are expected to develop pre-service and in-service teachers' awareness of environmental issues and play an active role in addressing environmental issues. In the future and current role, they will play an active role in addressing environmental problems by engaging students' awareness in environmental problems.

Green chemistry integration was designed with constructivism approach, where students are required to play an active role both in the learning process and daily lives. There are four important stages for students' awareness (Rahmawati, 2008):

1. *Performances Role Awareness*. Students have an awareness of its role, both as individuals and social agents in the environmental problems
2. *Environmental Awarenees*. Students have an awareness of environmental issues by chemical processes
3. *Green Chemistry Awareness*. Students have knowledge about the role of Green Chemistry in addressing environmental problems
4. *Active Contribution*. Students actively contribute to addressing environmental issues through Green Chemistry approach.

In designing a learning experience, students were required to make a project work that produces solutions to environmental problems, such as making a practical procedure with the approach of Green Chemistry. In the end, this course provides a positive contribution to environmental issues.

Based on the characteristics of courses outlined in the curriculum development, the courses are designed with this approach:

1. Students understand themselves and their role in the future.
2. Students have the ability to provide solutions to environmental problems related to Green Chemistry
3. Students analyse the comprehensive approach of green chemistry from various fields of chemistry studies.
4. Students plan the implementation of Green Chemistry approach in teaching and learning both in classroom and laboratory activities.

This learning experiences has stimulated students' reflection on their future role, and actively contribute to solving the problems in society, particularly related to the implementation of Green Chemistry.

In the classroom, the learning experiences started by asking their identity as teachers. They reflected on their motivation as teachers. Then, students were constructed their knowledge of environmental problems and green chemistry through analysis the issues given in articles. Students are required to discuss the environmental issues, so they developed the awareness of environmental problems, especially in Indonesia. The next reflections were continued on their future and current role as chemistry teachers on their contribution for solving environmental problems through education.

Students also integrate the concept of Green Chemistry through semi micro equipment in laboratory experiments. This relevant to the green chemistry concepts on reducing the volume. Then some laboratory experiments were also developed by reduce the volume and change to less dangerous chemical substances. In this stage, the students also understand the characteristics of chemical substances and its waste. In this context, students developed their contribution in reducing the laboratory chemical waste.

4.2. Implications of Green Chemistry Approach Integration

Implementation of integration of green chemistry approach has empower students in understand their identity as chemistry teachers and roles in environmental sustainability. There are three major themes that are found in this study:

4.2.1. Teachers Identity

At this stage, students are asked to reflect on their identity as teachers. Most of students realised that being teachers were the inspiration since their childhood. However, few of them chose for being teachers, because of their parent choices and rejected by well-known university. Besides, they realised that their identity were mostly developed by internal factors such as values and beliefs of being teachers means a good person. It is also influenced by the religion that teachers are privilege job for getting God's blessing. Most in-service teachers love their job of being chemistry teachers. The reflection of their identity helps them to find their motivation on empower their students, especially in their awareness of environmental problems.

After reflections, I realise my role as a chemistry teacher who can empower my students, not only develop students' knowledge in chemistry, but also empower them to active participate for environmental sustainability.

(Student Reflective Journal, October 17, 2016)

I love for my future role as a teacher who has role for providing learning experiences for my students' future roles

(Student Interview, October 13, 2016)

After the students to reflect on their role in the future, the lecturer facilitate their identity development to clarify their roles from different perspectives. Students has to be aware the importance understanding themselves as teachers before they empower their students. The pre-service and in-service teachers need to realise that within the different problems of education system in Indonesia and limited space for their creativity as teachers, they still have opportunity to contribute other aspects of students learning. As chemistry teacher educators, we equip our students teachers to have the integration of personal and social competencies which help them to participate in their role-life performances. According to Robertson and Gerber (2001), development of children's identity requires an understanding of themselves and social world. We realised that students teachers as individuals who have feeling, emotions, and intelligence which guide us to shape them as holistic individuals. Therefore, we develop the learning experiences which adheres to interpersonal relationships, development of self-awareness, self-development, engagement, and personal experiences. Thus, this reflection was powerful to stimulate their envisioning, understand themselves, and think about their future roles as chemistry teachers.

4.2.2. Students' Awareness of Environmental Sustainability

Every learner is unique which has own learning process. Moreover, teacher could explore varied strategies which give opportunities for students to explore and reflect on their ideas based on their lived experiences. As a result, the learning process becomes meaningful and powerful. In this way, the education process is recognized as a powerful process for shaping the generation. It is important to critically reflect on students' values of sustainability education before starting to empower their students. As current and future chemistry teachers, they discovered that it is not simply providing learning material on environmental issues to the students or to introduce green chemistry. It is about integrating the value of sustainability education in their teaching and everyday life. They recognised that the process requires an integrated approach, as there are several solutions from economic, social, political and educational viewpoints which are purposeful in achieving environmental sustainability. Nevertheless they believed that the solutions cannot be effective if those aspects don't integrate and humans don't engage with the environment. In Indonesia, environmental education is integrated in the curriculum as part of chemistry teaching. They have realised that to achieve the holistic process of environmental education, chemistry teachers should engage with education as sustainability, rather than only education about sustainability which merely teaches the subject or includes in the curriculum a topic on the environment. Here are several students' voice their awaransess on the environment within their roles.

*After I learnt Green Chemistry, I have better understanding of Green Chemistry concepts and principles. I became more conscious of environmental problems
(Students Reflective Journal, October 6, 2016)*

*The learning experiences make me realise and try to apply it in everyday life
(Student Interview, October 13, 2016)*

Based on student feedback, most students understand the concept of Green Chemistry were integrated and realise the importance of environmental sustainability. It has empowered them to participate actively in the implementation of Green Chemistry. The implementation of Green Chemistry in learning and learning are expected to provide a comprehensive understanding and active contribution of students. The issues that they were interested was the research and

development of environmentally friendly chemical products, recycling of waste, and reduce the environmental waste.

4.2.3. Envisioning for Current and Future Roles as Chemistry Teachers

Envisioning process could bring the students to be aware of their role in the society after leaving the teachers education program. Therefore, it is powerful to engage my students throughout the envisioning process. According to Robertson and Gerber (2001), it is important for the young generation to construct the positive image of the future which could affect the future of society. Furthermore, throughout the integration the idea of environmental awareness, sustainability, eco-justice, social justice, democracy, community, agenda for social reconstruction in the learning experiences, so that that they active participate in the reconstruction of society. Some reflections of students are:

*I will apply Green Chemistry in my teaching and laboratory experiments because Green Chemistry is very important in chemistry learning and very useful for environmental sustainability
(Student Reflective Journal, 13 Oktober 2016).*

*When I become a teacher in the future, , I will develop my students' awareness of environmental sustainability, especially the environment damaged by chemicals from plant waste then introduced what Green Chemistry is and introducing dangerous chemicals and that not harmful to students. Once the students know the concept of Green Chemistry, students are taught to apply it in practical activities by minimizing chemicals used, saving chemicals and applying leaching chemical tools that have been used with water flowing so that the concentration of a chemical used to decrease so it is not too dangerous for the environment
(Student Reflection, 10 November 2014)*

*If I become a teacher in the future, the thing I will do is reducing the dangerous chemical substances, teaching the impact of chemicals on the environment, apply the environmentally procedures in the laboratory
(Student Reflection, October 17, 2016)*

Most of the students stated the implementation of green chemistry in learning, especially learning chemistry is very important because it is useful for environmental sustainability. Integration of green chemistry has helped them in building a sense of awareness to the environment, understanding the concepts and principles of green chemistry, applying the green chemistry concept in learning experiences, especially in laboratory experiments by minimizing the use of chemicals, reducing the volume of chemical substances, reducing the concentration of the solution, using environmentally friendly chemicals, and considering the environmental friendly waste disposal

Integration of Green Chemistry in both the laboratory and learning experience in the classroom, not only contribute for reducing the negative impact to the environmental, but also developing their awareness of their future roles. Knowledge and understanding of environmental issues through experiential learning becomes important. The integration of green chemistry into curriculum and designing learning experiences has formed the oriented green chemistry students to think critically, reflective, and creative. Students were required to think critically about environmental issues, and reflect on their roles to solve these problems.

The learning experiences play an active role in improving the student's role as the young generation in addressing environmental problems. According Gadotti (2003), the environment's preservation depends on the ecological awareness which will be powerful to promote to the young generation throughout the education process. Education as an ethical enterprise might teach young

people to value their world and the very ecosystem that sustain life (Morris, 2002). The learning experiences were designed to stimulate students to care about the issues in their environment from their chemistry perspectives. According to Chambers and Rowell (2007), environmental issues topics in science curricula could promote the students' awareness of the social, economic and political dimensions in the society. Other implications of integration of Green Chemistry which is not detailed described in this paper is collaboration, critical thinking, empathy communication, and learning reflection. The students give a positive perception of the integration of learning Green Chemistry, in particular on the implementation of Green Chemistry.

5. Conclusion

Chemistry teacher education program needs to integrate the values of environmental sustainability as the environmental problems, especially because of the hazardous and toxic chemicals has negatively impact on health and the environment. Teachers' awareness and active participation will contribute to solve the problems.

Green chemistry plays an important role in efforts to prevent or reduce the impact of toxic and harmful chemicals to human health and environment. Green chemistry has 12 principles that can be integrated into the curriculum, applied in chemistry learning in the classroom and practical activities in the laboratory. Green chemistry can provide students with positive attitude for environmental sustainability to develop understanding and awareness to protect the environment.

The integration of green chemistry has implications on pre-service and in-service students in understanding their teaching identity, awareness of environmental problem, and envision their contribution in their current and future roles as chemistry teachers. Integration green chemistry by students' reflections provide the opportunity for students to develop their holistic awareness of its role in the future.

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7. References

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