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On the Development of Learning Designs for the Inclusion of Indigenous Science in the Context of Chemistry Education to Foster Education for Sustainable Development

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ABSTRACT
This paper reports a three year research and development project on the design of a lesson plan based on an educational research framework for the inclusion of a local indigenous cultural context into chemistry education. The research was intended to foster education for sustainable development (ESD) and to enhance the relevance in chemistry learning by integrating intercultural and multi-perspective scientific worldviews. The development of the learning designs involved different research phases, namely (a) exploring the content and context of indigenous science related to sustainability issues for their use in chemistry education, (b) implementing teaching interventions to identify students' views towards the topic and the lesson plan, and (c) investigating the students' ideas and arguments related to the issues in question. In search of effective implementation of learning designs, two lesson plans and corresponding teaching and learning materials were developed. Selected aspects from the implementation are described.

Keywords: *Chemistry education, Curriculum development, Indigenous knowledge, Education for sustainable development*.

1. INTRODUCTION

Based on the Agenda 21, the UNESCO has launched the world Decade for Education for Sustainable Development (DESD) from 2005-2014 [1]. This program was proposed to integrate education for sustainable development (ESD) into education in all subjects and on all educational levels, among them secondary and tertiary chemistry education. This program was suggested necessary to equip the future generation with important skills to participate in sustainable development and to live sustainably in the future.

In parallel to the DESD, ESD has started to become implemented in secondary chemistry education slowly and basically starting from Western countries, e.g. [2] [3] [4]. Indications from the implementation of ESD suggest that ESD in chemistry education can promote the relevance of science learning in terms of relevance for students' individual daily lives, their life in society, and with relationships to potential careers [5]. The implementation of ESD in Asian countries, especially in Indonesia, so far stepped behind. Its implementation was limited to short programs only and mainly restricted to higher education [6] [7]. Therefore, the development and implementation of curricula that support ESD in chemistry education in Indonesia are required.

Content and contexts for ESD should take the living context of the learners into consideration, e.g. in terms of Indonesia, referring to the geographical, cultural, and socio-economic conditions of Indonesian students [8] [9]. Indonesia is a multi-ethnic and multi-cultural society. There is a lot of traditional knowledge, known as indigenous knowledge, that instills local wisdom and values about nature and sustainable use of natural resources to meet the needs of local societies [7] [10]. This knowledge includes the application of scientific concepts and practices (indigenous science) in combination with culture and philosophical values that are respected in the corresponding society to protect nature and achieve sustainability [11]. This indigenous knowledge context is suggested to have potential to be integrated into science and chemistry learning to contribute to ESD [7] [11].

Research and development on the inclusion of indigenous knowledge in the context of chemistry learning to foster ESD has been increased during the last years [7] [8] [10] [11] [12] [13]. First studies attempted to reconstruct and integrate indigenous knowledge into the science curriculum in Indonesia on the upper secondary school and university levels. This paper reports the process of curriculum development on the inclusion of the indigenous knowledge of the Baduy community into chemistry education and reflecting on its implementation.

2. THEORETICAL FRAMEWORK

The educational design framework for this project intended to integrate indigenous science and indigenous perspectives on sustainability into chemistry education in Indonesia. The design process was guided by an educational research framework (Figure 1) [11] adapted from the Model of Educational Reconstruction (MER) [14]. This educational research framework integrates views from indigenous knowledge and Western modern science to analyse content structures and related contextual knowledge for evidence-based curriculum development and research on teaching and learning based in altered or newly developed learning designs.

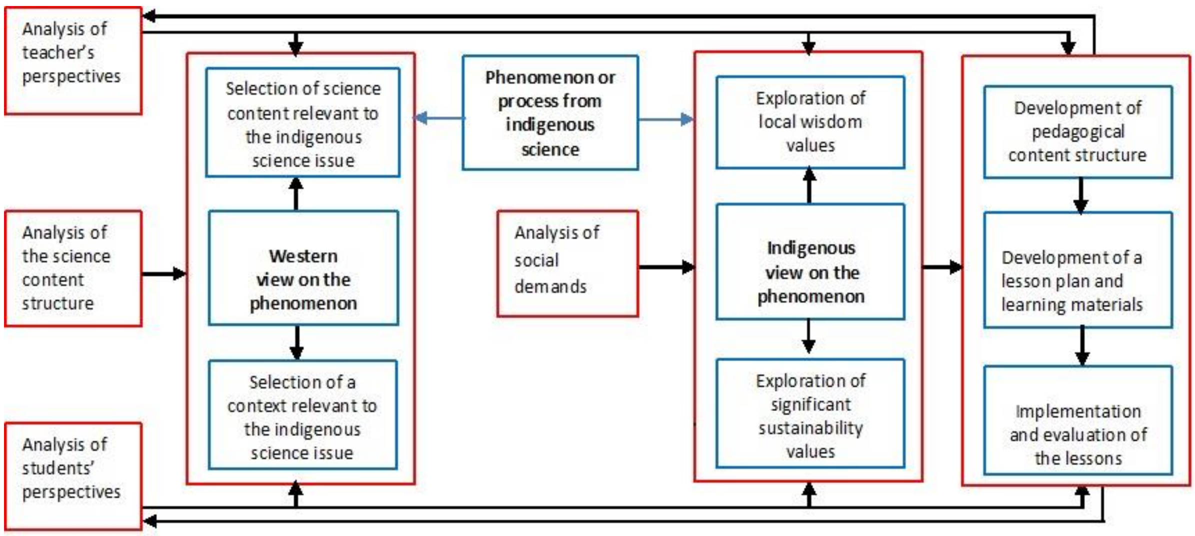

Figure 1 Educational design framework to reconstruct and integrate indigenous science and Western modern science for curriculum development in science education [11].

3. RESEARCH PROCESS and FINDINGS

The research and development process has been conducted over three years. The focus was the inclusion of indigenous knowledge into the context of chemistry education. The study was conducted with student teachers and upper secondary school students to evaluate potential effects of learning designs.
According to the educational research framework in Figure 1, the curriculum development process included three phases, namely (1) exploring indigenous science related to relevant sustainability issues, (2) developing the teaching interventions and identifying students' perspectives toward the topic, and (3) mapping students' views and arguments on the application of indigenous science.

3.1 Exploration of indigenous science related to sustainability issues for its use in chemistry education

The initial study was an ethnographic research to explore indigenous science relevant to chemistry education in Indonesia [10]. This research was related to a general clarification of the concept and analysis of the state-of-the-art of using indigenous science in science education [11]. The ethnographic study involved observations, interviews and focus group discussions with the indigenous people of the Baduy on Java, Indonesia. A triangulation of data was utilized to ensure validity by comparing the field data with other existing literature related to indigenous science of the Baduy community. Based on the data, the inventory of indigenous science was further analysed to see any relationship to the content in the Indonesian chemistry education curriculum. The analysis encompassed thematic analyses focusing exemplary topics to be used as contexts for chemistry learning. The content and contexts identified in the indigenous science of the Baduy were reflected based on five criteria for selecting socio-critical and problem-oriented issues for science teaching [15] with relation to a context-based socio-constructivist pedagogical approach as described by Juntunen and Aksela [16]. This analysis identified potential topics from indigenous science related to sustainability to be used for socioscientific issues-based chemistry learning [7] (Figure 1).

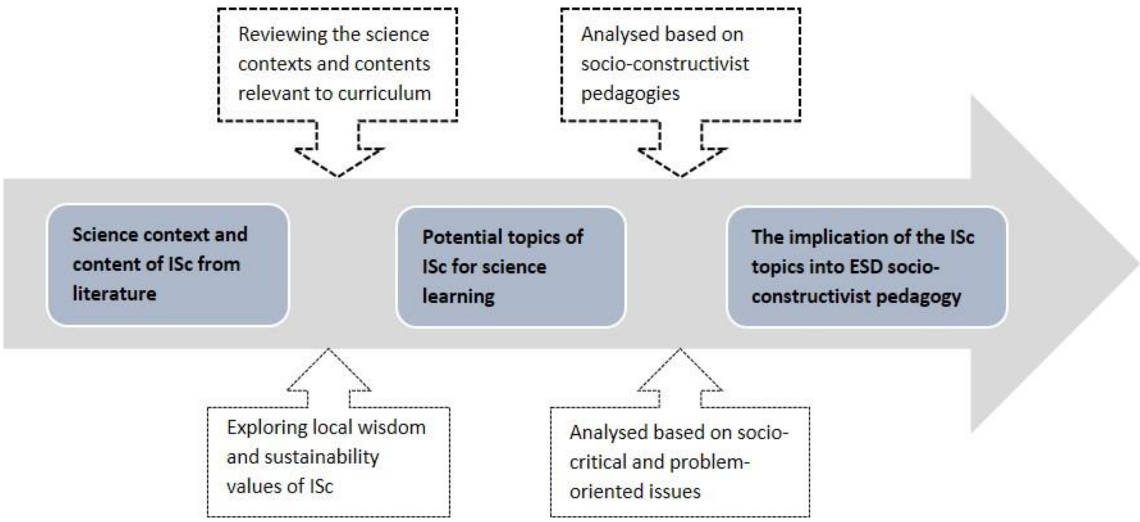

Figure 2 Analysis of integrating indigenous science (ISc) into socio-critical and problem-oriented chemistry education [7].

From the analysis, the topic of pesticides use was chosen for updating chemistry learning related to sustainability and inspired by indigenous knowledge. The topic was called “Bio-rational control of pest insects using indigenous materials vs synthetic pesticides”. It was inspired by the local wisdom, philosophy and sustainability values of the Baduy community, who utilize botanical pesticides from indigenous plant extracts to repel pest insects. The related chemistry content of the topic encompasses organic compounds, pesticides, phytochemistry, and analytical chemistry. The sustainability aspects to be learned from this topic are to learn about risk-benefit analysis between synthetic and green pesticides as well as green chemistry approaches to isolate and explore eco-benign pesticides [7]. For implementing the topic into chemistry education, green chemistry principles can become an issue for the practice of science education practical work, sustainability strategies can become content in the chemistry curriculum, and socio-scientific issues-based learning can be operated [17].

3.2 Developing the teaching interventions

In the research and development process, two learning designs were produced. The first learning design focuses the controversial sustainability issues of pesticides use from the perspectives of indigenous knowledge and Western modern science. The second learning design attempts to introduce indigenous knowledge as a starting point to learn about green and sustainable chemistry and corresponding practical work.

3.2.1 Leaning design 1: Chemistry learning about pesticides use based on different perspectives taken from indigenous and Western modern science

The first learning design focuses on the controversial sustainability issue of pesticides use. The lesson plan was developed with two groups on different educational levels, encompassing upper secondary school students and university chemistry student teachers in Indonesia. The main activities start from the controversial issues of pesticides use to encourage learners to think critically, express their arguments, and solve chemistry problems behind the issue. The description of the lesson plan is given in Table 1.

Table 1. The first learning design on pesticides use in chemistry education

Learning Steps	Description
Step 1: Exploring prior personal knowledge	- Brainstorming what students know about pesticides use - Discussing any knowledge about the context or topic - Identifying students' initial ideas and opinions connected to the chemistry context of the lesson plan
Step 2: Introducing the context and controversial issue	- Exploring the context of pesticides use from various sources of media - Analyzing the global perspective of pesticides use - Provoking controversial questions about pesticides use
Step 3: Initiating multi- perspective thinking from indigenous and Western modern science	- Analysing multi-perspectives from indigenous and Western modern science on pesticides use - Identifying the science, values, philosophy and local wisdom of indigenous knowledge from the Baduy to complement Western modern science (chemistry) views - Analysing potential alternative solutions from the perspectives of indigenous knowledge and Western modern science.
Step 4: Connecting the context with chemistry concepts	- Providing the connection between relevant chemistry concepts related to pesticides use - Providing problem-solving questions that engage students to apply chemical concepts behind the topic
Step 5: Meta-reflection	- Considering the consequences of the two different perspectives - Considering the potential of collaboration and shared visions between different perspective - Reflecting the process of decision making toward the issue - Reflecting students' individual or group actions - Reflecting future deliberations

The implementation of this first learning design indicated that this lesson plan is appropriate for university-level chemistry education [8]. The topic of pesticides use seems to be suitable for university chemistry teacher education because it deals with a complex issue to promote higher critical thinking skills and a stronger foundation of chemistry content knowledge [12]. The learning design engaged students with both basic chemistry content knowledge, indigenous knowledge and how this knowledge and the application of science in a societal debate can be evaluated and reflected. The learning design has potential to support the development of important skills. These skills include decision making, argumentation, choosing appropriate information, and collaboration. For upper secondary school chemistry, the teaching intervention might need improvement in terms of better connecting the chemistry knowledge related to issues to the context. For applying this learning design in secondary school chemistry, the basic chemistry content knowledge behind the issue needs to be strengthened before so that the students would be able to engage the chemistry concepts better with the socio-scientific issue [12].

3.2.2 Learning design 2: Using indigenous knowledge as a starting point to learn about green and sustainable chemistry along pesticides use

The second learning design attempted to facilitate students learning about green and sustainable chemistry inspired by indigenous knowledge. The lesson was implemented in an elective environmental chemistry course for university chemistry student teachers. The learning activities started from the context of indigenous chemistry (ethnochemistry). From this information, students conducted investigations on green and sustainable chemistry and green laboratory work inspired by ethnochemistry. Table 2 describes the lesson plan of the second learning design.

Table 2. The teaching sequences of the second learning design

Learning Steps	Description
Step 1: Exploring ethnochemistry and related information from green chemistry	- Exploring information about ethnochemistry related to the topic of pesticides use from various media - Exploring the general context of pesticides use by internet search (what are pesticides, their functions and types, green pesticides and their characteristics, etc.) - Exploring the concept of green chemistry and its application
Step 2: Exploring the chemistry concepts behind ethnochemistry	- Using online chemical information databases and research papers to understand the phytochemical concepts behind ethnochemical use of bio-pesticides - Discussing the finding with the teacher to get feedback
Step 3: Exploring the chemistry concepts behind ethnochemistry by various chemical experiments	- Conducting or observing the investigation of chemicals or phytochemicals from ethnochemistry using various laboratory techniques - Predicting and identifying the chemicals compounds that can be used as alternative green and sustainable pesticides
Step 4: Discussion of experimental results	- Discussing the result of the experiments in student groups - Getting feedback from the teacher
Step 5: Evaluating laboratory methods based on green chemistry	- Comparing and evaluating different extraction methods using green chemistry criteria - Deciding the best method that mostly represents green chemistry

The implication of the second learning design showed positive feedback from the students [13]. The learning activities facilitated the students to learn chemistry across cultures inspired by ethnochemistry. This lesson plan also motivated students to learn chemistry from local culture. In addition, the learning sequences also provided the students with content and hands-on and minds-on activities related to green chemistry, especially in practical works. This lesson plan, however, tended to provide less engagement with the reflection on chemistry applications in society, which is a major focus of ESD learning. As a consequence, general skills that are important for students to participate in social debate on socio-scientific issues are hard to achieve. On the other hand, learning about green and sustainable chemistry as the contribution toward sustainable development can be accommodated by this learning design and also forms a part of ESD.

3.3 Identifying students' views and arguments on the application of indigenous science

During the teaching interventions of the first learning design, students were involved in group discussions to share their arguments about the sustainability issue of pesticides use based on the different perspectives from indigenous and Western modern science. At the end of the lesson plan, the students had to answer chemistry problem-solving questions connecting the concepts of chemistry learning with the indigenous context of the lesson plan. Findings from the analysis indicate that both upper secondary school students and university student teachers broadened their spectrum of arguments related to the sustainability-relevant chemistry issue of pesticides use under inclusion of different scientific worldviews, especially in the category of ethical arguments. In terms of the application of chemical content, the university students showed a much better understanding of the chemical concepts compared to upper secondary school students [12].

4. CONCLUSION

Curriculum development in this project on the inclusion of indigenous knowledge in chemistry learning has produced two learning designs that can be implemented in both upper secondary school and university level chemistry education. Teaching interventions were carried out involving upper secondary school students and chemistry student teachers in Indonesia. The finding indicates that the topic was considered relevant and interesting by the students. The lesson plans were perceived to encourage students' learning of chemistry enriched by reflecting different interconnected worldviews to find solutions to sustainability issues. The choice of the learning design, however, should consider the level of education and students' thinking abilities. Each learning design has the advantage in accordance with the skills, knowledge and attitudes that teachers want to instill in students. It depends on the needs of the curriculum and learning purposes that are suggested to be achieved. Further research should aim at identifying further topics from indigenous science to be implemented in secondary and higher chemistry education to benefit from indigenous knowledge and its motivating potential for chemistry education, in Indonesia and beyond. It also needs further research to find out how generally positive the inclusion of indigenous knowledge is for chemistry education whilst comparing cases from different societies and cultures.

AUTHORS' CONTRIBUTION

Robby Zidny: conceptualization, method, data curation, visualization, editing, drafting manuscript. Ingo Eilks: Review, conceptualization, and editing of manuscript.

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