The Model of Educational Reconstruction: Integrating Content and Nature of Science in Teaching Materials

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Abstract—To improve instructional practices has been a major concern of science education research and development. The teaching and learning of science is the main focus of science education. The model of educational reconstruction (MER) is a widely used research programme that was developed to improve content specific learning and teaching. The MER integrates the perspectives of students and scientist in order to design learning environments. By example of an educational reconstruction of content and nature of science we show how the MER can help to analyse, design and evaluate learning environments fostering a conceptual understanding. Helping students develop informed views of nature of science (NOS) has been and continues to be a central goal for kindergarten through Grade 12 science education. Our focus is on ideas about the reconstruction of integrating content and nature of science in teaching materials. First we examine about MER in science education, next we provide an overview of recent developments about NOS, and the last we give an example how to integrate content and nature of science in teaching materials using model of educational reconstruction.

Keywords: MER, NOS, science education, teaching materials

I. INTRODUCTION

Science education is concerned with the teaching and learning of science content and practices. The teaching and learning of science is the main focus of science education. It requires fruitful strategies to engender a conceptual understanding. The goal of Model of Educational Reconstruction (MER) is to improve content specific learning and teaching. The MER integrates the perspectives of students and scientists in order to design learning environments.

The MER provides a broadly conceived approach for subject-matter education research. It provides a frame for research to design teaching and learning sequences that are relevant for improving instructional practice [6]. The MER integrates the perspectives of students and scientists in order to design learning environments. The MER strands on two feets-one foot in the discipline and other in education. Both perspectives are brought together to design domain-and topic-specific theories of teaching and learning science. The design is lead by learning capabilities of the students on the one hand and clarification of science content on the other hand. The MER presented in this chapter provides a conception of science education research that is relevant for improving instructional practice and teacher development program.

Teaching and learning in science education is not only focus on the knowledge of science (content of science) but also knowledge about science (nature of science). Therefore, teaching the understanding about Nature of Science (NOS) should be conducted while teaching the content. But, in some countries (especially in Indonesia), understanding about NOS does not explicitly embedded in teaching and learning of science. So, teaching materials which integrate content and NOS are important to help teachers for teaching content and NOS simultaneously. Reconstruction of teaching materials is needed to produce the teaching materials. MER can be used to reconstruct and design the teaching materials.

II. DISCUSSION

A. MER in Science Education

The Model of Educational Reconstruction (MER) is a framework for research on content specific teaching and learning. A key concern of the Model of Educational Reconstruction (MER) is that science subject matter issues as well as student learning needs and capabilities have to be given equal attention in attempts to improve the quality of teaching and learning. Reconstruction means the process that transform (or translate) domain
specific knowledge into knowledge for instruction [14]. The content structure of the discipline differs from the content structure for instruction in that the latter is reduced to the elementary ideas but also enriched by contextual embedding and customizing and thereby reconstructed. Teachers or researchers (in this model) working with the model analyse, design and evaluate instructional approaches striving to facilitate learning and teaching. The results of this model is content-oriented theories on conceptual development (design-based research) as well as in evidence-based and theory guided analysis, design and evaluation for learning environment. There are three major emphases that are intimately connected in MER as in [6], i.e:

1) The clarification and analysis of science subject matter (including key science concept and principles like evolution, energy, particles, or combustion, and science processes and views of nature of science, as well as the significance of science in various out of school contexts).

2) The investigation into student and teacher perspectives regarding the chosen subject (including pre-instructional conception, affective variables like interest, self-concepts, attitudes, and skills).

3) The design and evaluation of learning environments (e.g. instructional materials, learning activities, teaching and learning sequences).

Three components of the MER as in [14] are almost similar to the [6], i.e. 1) clarification of science content, 2) critical analysis, and 3) analysis, design, and evaluation of learning environment. The differences are the process of analysis as in [14] done at the last major emphases and the critical analysis just focusing at the students’ perspectives. The other major emphases are the same as in reference [6]. Clarification of science content draws on qualitative content analysis of reliable source like leading textbooks on the topic under inspection. The aim is to clarify the specific science content structure as constituted by the related conceptions from an educational point of view [14]. A critical analysis is necessary because academic textbooks address experts and present knowledge in an abstract and condensed manner that is not accessible for novice learner. It is also widely accepted by science educators that it is necessary to take the students’ prior conceptions into consideration within the learning discourse. Investigation into students’ perspectives aims at pre-instructional conceptions and conceptual development. Analysis, design and evaluation of learning environments refer to instructional materials, learning situations, and teaching and learning sequences.

The teachers or researcher should perform the “design of learning environments” after iterating the two first steps “investigation into students perspectives” and “clarification of science content”, aiming to adopt subject matter knowledge as presented in textbooks or other scientific publications to the perspectives of the students in such a way that suitable teaching content could be constructed. Figure 1 points to the fundamental interaction between the three components of the MER. Each of the three components was regarded as equally important [8]. However, the three components do not strictly follow upon another but influence each other mutually. Consequently the procedure must be conducted step by step recursively [14]. Reference [6] depicts the research design which is derived from the model of educational reconstruction. Reference [14] gives the example of idealized process of actual research progress of the educational reconstruction of climate change.

![Figure 1. The Model of Educational Reconstruction as Proposed by Kattmann et al. [8]](attachment:figure_1.png)
FIGURE 2. RESEARCH DESIGN DERIVED FROM THE MODEL OF EDUCATIONAL RECONSTRUCTION

The example of idealized process of actual research progress of the educational reconstruction of climate change as in [14] started with parallel analysis of scientists’ conceptions and students’ conceptions (1). After mutually relating them to each other, a deepened analysis of students’ conceptions to the scientists’ conceptions in an interview study followed (2). These conceptions to the scientists’ conceptions were related (3) and the results of this was taken for the development of teaching guidelines (4). These teaching guidelines were operationalized in learning environments. The cornerstone in designing learning environments within the MER is the teaching experiment. In the teaching experiment the interviewer asct as researcher adn the teacher at the same time. (5). This learning environments were probed in a formative evaluation by teaching experiments (6). Based on the analyses, the research resulted in empirically evaluated learning environments and the description of students’ conceptions and their conceptual development in working with these learning environments (7). Additionally clarified key concepts relevant for teaching climate change were gained.

B. Nature of Science (NOS)

Nature of Science (NOS) has long been promoted an important content of science education [9] and has consequently been included in multiple standard document worldwide e.g AAAS, 1993 [2]; National Research Council, 1996 [11]; McComas & Olson, 1998 [10]; NGSS Lead States, 2013 [13]. The interdisciplinary nature of science education is responsible for particular challenges for carrying out science education research and development. Not only sound competencies in science are necessary but also substantial competencies in various additional disciplines. In principles the same set of competencies-though with different emphases-has also to be expected from teachers. To know science well is not sufficient for them. At least some basic insight into the nature of science provided by the philosophy and history of science and familiarity with recent views of teaching and learning science provided by pedagogy and psychology are needed [6].

An understanding of the Nature of Science plays an important role in the development of scientific literacy. Besides viewing knowledge about the nature of science as an important for its own value with respect to scientific literacy, an adequate understanding of NOS is expected to improve science content learning by fostering the ability to interrelate scientific content, and thus, coherently acquirescientific content knowledge [5]. A Framework for K-12 Science Education [12] acknowledged the importance of the nature of science in the
statement’…there is strong consensus about characteristics of the scientific enterprise that should be understood by an education citizen. The framework reflected on the practices of science and returned to the nature of science in the following statement: “epistemic knowledge is knowledge of the constructs and values that are intrinsic to science. Students need to understand what is meant, for example, by an observation, a hypothesis, and inference, a model, a theory, or a claim and be able to distinguish about them.

The difficulty here is that there is no specific description for appreciation the exact nature of science [7]. In general, the nature of science refers to key principles and ideas which provide a description of science as a way of knowing, as well as characteristics of scientific knowledge [15]. NOS refers to the epistemological underpinnings of the activities of science and the characteristic of resulting knowledge [9]. The phrase “nature of science” typically refers to the epistemology of science, science is a way of knowing, or the values and beliefs inherent to scientific knowledge or the development of scientific knowledge. Beyond these general characterizations, no consensus presently exist among philosophers of science, historians of science, scientists, and science educators on specific definition about NOS. hence, the reason for not placing the word “the” in front of NOS [1].

Although there is not agreement about the definition of nature of science, there are some agreements about the aspect of understanding about NOS. The basic understanding about the nature of science included in the Next Generation Science Standards are:

1) Scientific investigations use a variety of methods
2) Scientific knowledge is based on empirical evidence
3) Scientific knowledge is open to revision in light of new evidence
4) Scientific models, laws, mechanisms, and theories explain natural phenomena
5) Science is a way of knowing
6) Scientific knowledge assumes an order and consistency in natural systems
7) Science is human endeavor
8) Science addresses questions about the natural and material world.

The first of these understandings are closely associated with practices and the second four with crosscutting concepts.

The basic understanding about nature of science as in [9] are:

1) Scientific knowledge is tentative (subject to change)
2) Scientific knowledge is empirical based (based on and/or derived from observations of the natural world)
3) Scientific knowledge is subjective (involves personal background, biases, and/or is theory-laden)
4) Scientific knowledge necessarily involves human inference, imagination, and creativity (involves the invention of explanations)
5) Scientific knowledge is social culturally embedded.

Two additional important aspects are the distinction between observations and inferences, and the functions of and relationships between scientific theories and laws.

However, teaching about nature of science sometimes gets lost as it is embedded in regular science instruction. Nature of science in science instruction should be formal and as much as an aspect of subject matter as pH, stages of the life cycles, or the components of the water cycle. That means that we should provide explicit instruction on nature of science [4]. When students carry out an investigation, develop models, articulate questions, or engage in arguments, they should have opportunities to think about what they have done and why. They should be given opportunities to compare their own approaches to those of other students or professionals scientist. Through this kind of reflection they can come to understand the importance of each practice and develop a nuanced appreciation of nature of science [3]. For example, scientists develop their ideas based on evidence and they change their ideas when new evidence becomes available or the old evidence is viewed in a different way. Designing lessons around science topics or concepts that have changed over time can help students understand more about nature of science. Such lessons show students that scientific knowledge in and of itself is not static and that with new information, scientific theories can change. In the lesson, the instruction must be explicit on “how” knowledge has changed and why, e.g. students might get this idea from a lesson or discussion about the solar system and how very recently scientists have just decided that there might be a tenth planet [3].

As we teach these aspects of nature of science, secondary students will be better able to connect what they are doing in their science classrooms to the work of scientists. This explicit approach to teaching nature of science also enables teachers to help students better understand the changing claims that scientists make everyday in television and in the newspapers.
C. Integrating Content and Nature of Science (NOS) in Teaching Materials using MER

There are several reference disciplines that are needed to meet the challenges of investigating and analysing key issues of teaching and learning science. The Philosophy and history of science provide thinking patterns to critically analyze the Nature of Science (NOS) [9,10]. Besides viewing knowledge about the NOS as an important for its own value with respect to scientific literacy, an adequate understanding of NOS is expected to improve science content learning by fostering the ability to interrelate scientific content and, thus, coherently acquire scientific content knowledge [5].

Initially, the focus of MER was on studies on educational reconstruction of science content. More recently, it became clear that also science processes and view of the nature of science need to undergo this process in order to allow efficient learning and teaching of issues about science [6]. Addressing the need for students to understand both the concepts and practices of science and the nature of science is not new in American education. The MER closely links research on the science content structure and the educational significance of parts of it, and also includes empirical studies on students’ understanding as well as preliminary trials of pilot instructional modules in classroom practice.

The Model of Educational Reconstruction (MER) can be used for integrating content and NOS in teaching materials, by the steps of: 1) analysis of scientist’s conceptions about specific content and NOS; 2) design and evaluation of learning environment focusing in teaching materials; 3) analysis of students’ conceptions about specific content and NOS after using the teaching materials which integrating content and NOS.

III. CONCLUSION

Nature of Science (NOS) is an important material that must be known by all children. Content and NOS can be integrated in teaching materials for improving student’s scientific literacy and science content learning. The Model of Educational Reconstruction (MER) can be used for integrating content and NOS in teaching materials, by the steps of: 1) analysis of scientist’s conceptions about specific content and NOS; 2) design and evaluation of learning environment (focusing in teaching materials); 3) analysis of students’ conceptions about specific content and NOS after using the teaching materials which integrating content and NOS.

REFERENCES