Eurasia Journal of Mathematics, Science & Technology Education
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Received 11 April 2013; accepted 23 October 2013
Published on 20 November 2013

APA style referencing for this article: Stolz, M., Wittteck, T., Marks, R. & Eilks, I. (2013). Reflecting Socio-Scientific Issues for Science Education Coming from the Case of Curriculum Development on Doping in Chemistry Education. *Eurasia Journal of Mathematics, Science & Technology Education*, *9*(4),361-370.

Linking to this article: DOI: 10.12973/eurasia.2014.945a

URL: http://dx.doi.org/10.12973/eurasia.2014.945a

ISSN: 1305-8223 (electronic) 1305-8215 (paper)

Eurasia Journal of Mathematics, Science & Technology Education, 2013, **9**(4), 361-370

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Socio-scientific issue-based science education has been suggested for promoting general educational skills development in science classes. However, there is a lack of operationalized criteria, which can be used to reflect upon societal issues to whether turning them into issues for science classroom instruction. This paper describes a case study based on Participatory Action Research in science education. A lesson plan based on the socio-scientific issue of doping in professional sports and in fitness studios was designed and cyclically refined by a group of teachers and science education researchers. Along this case, together with previous studies of SSI-oriented curriculum development, the action research group started reflecting on the question of operational criteria for reflecting and carrying out socio-scientific issues in science classroom situations. This paper discusses the structure of the above-mentioned lesson plan. Experience gained during lesson plan development and testing will be reported upon. Suggestions stemming from teacher group discussions about the criteria chosen for reflecting socio-scientific issues for classroom use will also be presented.

Keywords: socio-scientific issues-based science education, curriculum development, participatory action research, doping, analytical chemistry education

INTRODUCTION

Quite regularly, science education in general and secondary chemistry education in particular have been listed among the most unpopular subjects among most students (Holbrook, 2008; Osborne & Dillon, 2008). A frequent explanation of this situation is that most science learners do not (or cannot) perceive the relevance of science and science education, especially in chemistry and physics. This results in low levels of student motivation (Jenkins, 2005; Osborne, 2003). One suggestion for improving students' perception of the relevance of science has been to strengthen the societal dimension of science education (Hofstein & Kempa, 1985; Holbrook & Rannikmae, 2007; Solomon & Aikenhead, 1994; Yager & Lutz, 1995). This dimension is quite often a very much neglected area in science education (Hofstein, Eilks & Bybee, 2011; Hughes, 2000). Some research has suggested that increasing the societal orientation of science education will better prepare students for life in future (Elmose & Roth, 2005; Ware, 2001; Sjöström, 2013) and raise their personal perceptions of the relevance of science education (Fensham 2004a; Holbrook, 2003; Lee & Erdogan, 2007).

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DOI: 10.12973/eurasia.2013.945a

Many people have promoted the use of socio-scientific issues (SSIs) as a possible driving force for skills-oriented science education (Sadler, 2004; 2011; Zeidler Sadler, Simmons, & Howes, 2005). SSIs should not only serve as motivating contexts for science

ISSN: 1305-8223

State of the literature

- A need for stronger inclusion of the societal dimension of science exists in most science classrooms.
- Socio-scientific issues have already proven themselves to be motivating and beneficial in the context of science education in previous studies.
- Socio-scientific issues in science education have the potential to promote both science learning and general educational skills.

Contribution of this paper to the literature

- This paper discusses how the issue of doping in sports can be used as a socio-scientific issue in science education.
- The current paper documents in-service experience, which shows that doping can be a motivating topic when used as a socio-scientific issue in science education.
- The results suggest several potential criteria that can aid educators in reflecting upon societal contexts in order to use them as socio-scientific issues in science education.

learning, but also provide a catalyst to spark general educational skills (Sjöström, 2013), like argumentation (Albe, 2008) and decision-making abilities (Simon & Amos, 2011).

Within the SSI-based science education movement, some ten years ago the socio-critical and problem-oriented approach to science education was developed in Germany. This approach originally saw the light of day in the 1990s with the introduction of a lesson plan centering around the use of biodiesel (Eilks, 2002a). Many later examples have been developed using the model of Participatory Action Research as a collaborative strategy for curriculum development and classroom-based research in science education (Eilks & Ralle, 2002). Teaching units have been published e.g. on low-fat, low-carb diets (Marks, Bertram & Eilks, 2008), musk fragrances in shower gels (Marks & Eilks, 2010) or the use of bioethanol as an alternative fuel source (Feierabend & Eilks, 2011). Different research-based suggestions for the science classroom were derived from these units. The resulting ideas include e.g. a five-step model to structure SSI-based classroom activity (Marks & Eilks, 2009) or new pedagogies, which mimic the processes how science-related information is both transferred and employed in societal debate (Eilks, Nielsen & Hofstein, in print).

This paper examines another example of the socio-critical and problem-oriented approach to science teaching developed by Participatory Action Research (Eilks & Ralle, 2002). The SSI of sports doping was selected as the context for promoting subject-matter learning as well as general educational skills, since it involves not only a background in science, but also societal decision-making processes regarding doping questions. During the cyclical refinement process, the Participatory Action Research group started focusing on refining criteria as originally suggested by Marks and Eilks (2009) necessary to effectively reflect upon questions taken from society for use as SSIs in the science classroom. This paper discusses both the lesson plan and the action research group's path towards a better understanding the reflection and selection of socio-scientific issues for classroom use.

METHOD

The current lesson plan was developed according to the model of Participatory Action Research (PAR) in science education (Eilks & Ralle, 2002) as it has also been suggested by Pedretti and Hodson (1995) to use Action Research to implement societally driven education in science classrooms. For more than a decade, many studies have been carried out that show PAR's potential for evidence-based curriculum design and for promoting continuous professional development of teachers (Marks & Eilks, 2010; Mamlok-Naaman & Eilks, 2012).

PAR is a collaborative process, which combines curriculum change with classroom-based research. University researchers and in-service teachers cooperate to merge evidence-based knowledge stemming from educational research with practical experience taken from classroom settings. Both sources constitute a knowledge spectrum, which is important for innovation in teaching and learning. Each area has its own strengths and weaknesses (McIntyre, 2005). The development and classroom-based research phases during PAR are part of a cyclical process (Figure 1). Lesson plans are collaboratively drafted, tested, evaluated, and then revised. Main focal points of the entire process include the improvement of authentic teaching practices and the continuous professional development of the practitioners. The process also aims at collecting empirical evidence which shows the effects of changed practices in the classroom and aids in the dissemination of innovative classroom practices (Marks & Eilks, 2010).

The lesson plan on doping was developed by a group of ten teachers from different schools in Germany, who worked together for over a decade prior to creating this teaching unit (Mamlok-Naaman & Eilks, 2012). This PAR group has also developed many similar lesson plans and carried them out in classroom situations (e.g. Marks & Eilks, 2010). The teachers and researchers meet regularly once a month for a whole afternoon. For

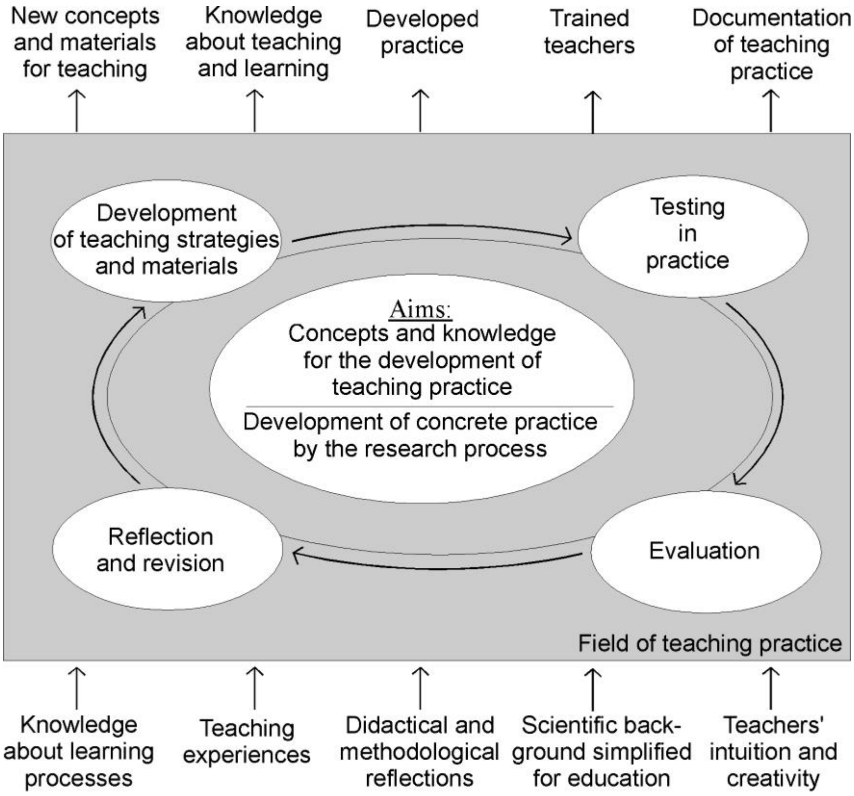

Figure 1. Participatory Action Research in science education (Eilks and Ralle, 2002)

this particular topic, the team needed about a year to finish the lesson plan.

By the end of the development phase, the lesson plan was tested in one tenth-grade and three eleventh-grade classes in German high schools. A total of 80 students (age range 15-17) took part in the case study. The data collected included teacher feedback during the group discussions in the monthly meetings of the action research group. Teacher reflection in this case was focused on finding potential criteria for effectively reflecting upon SSI-based topics in science education. A student questionnaire composed of open and Likert questions was also employed to record student feedback. Participants were asked about the feasibility of the lesson plan and their opinion of both the topic and how it was taught. The data sources were then qualitatively analyzed and triangulated to construct meaning.

The lesson plan

Socio-critical and problem-oriented science teaching

The socio-critical and problem-oriented approach to science education focuses on increasing learners' motivation and the perception of relevance in science teaching, just as similar approaches do (Osborne, 2003). This method attempts to explicitly prepare students to both understand and take part in societal consensus-building and decision-making processes dealing with technical and scientific questions. This approach is quite typical for socio-scientific issues-based curricula (Sadler, 2011).

The theoretical basis of socio-critical and problem-oriented science teaching points researchers towards a consistent model for structuring SSI-based teaching. After comparing teachers' development of SSI-based lesson plans in many case studies, Marks and Eilks suggested a model for structuring lesson plans in 2009. They outlined a set of goals within the model. These included: 1) an orientation centering on the unique German concept of "Allgemeinbildung" (general education) which has recently found its way into the international literature (Fensham, 2004b; Elmose & Roth, 2005; Hofstein et al, 2011, Sjöström, 2013), 2) a stronger link to the idea of 'education through science' rather than 'science through education' (Holbrook & Rannikmae, 2007), 3) a promotion of multidimensional scientific literacy (Bybee, 1997) and 4) skills development in the areas of communication and evaluation, particularly societally oriented argumentation and decision-making abilities. However, criteria for topic selection, some essential methodological components, and a tested pattern of the general steps in which the units tended to run were also addressed (Figure 2).

The socio-critical and problem-oriented approach introduces current, authentic science topics to the learners with the aid of everyday media. This includes

Objectives	Criteria for selecting issues and approaches	Methods	Structure of the lesson plans
Allgemeinbildung/ education through science	Authenticity	Authentic media	1. Textual approach and problem analysis
(Multidimensional) Scientific Literacy	Relevance	Student oriented chemistry learning and laboratory work	2. Clarifying the science background in a laboratory environment
Promotion of evaluation skills	Evaluation undetermined in a socio-scientrific respect	Learner centred instruction and cooperative learning	3. Resuming the socio-scientific dimension
Promotion of communication skills	Allows for open discussion	Methods structuring controversial debating	4. Discussing and evaluating different points of view
Learning science	Deals with questions from science and technology	Methods provoking the explication of individual opinions	5. Meta-reflection

Figure 2. Framework of socio-critical, problem-oriented science teaching (Marks & Eilks, 2009)

the use of magazine articles, newspaper clippings, radio and television broadcasts, and brochures published by special interest groups, businesses, industry, and both consumer protection and environmental agencies. The media samplings showcase the various opinions of experts and special interest groups with their unique points-of-view. Questions are then derived from the pupils close contention with the media materials. All questions which specifically require scientific or technological knowledge to understand are clarified during a phase of subject-matter learning and practical work. After this, reevaluating exactly which questions have been answered (or not) returns the learners to the socio-scientific dimension of the issue. Reflection on how society handles and evaluates SSIs is provoked by exercises which mimic authentic social practices. Various possibilities exist for contrasting societal perspectives on the topic with societal decision making processes. These include conventional exercises like role-playing and business games, but other methods can also be employed. New pedagogies originally created for socio-critical and problem-oriented science teaching include the journalist method (Marks, Otten & Eilks, 2010) and working as a professional product tester (Burmeister & Eilks, 2012). Each of these methods highlights a societal practice which communities use to discuss and evaluate socio-scientific questions. These practices are reflected upon in the final phase of the lesson plan with a special focus on how society deals with questions about science and technology (Eilks et al., in print). In end effect, such teaching units provide learners with access to controversial aspects of a problem, give them a techno-scientific clarification of important questions, then require them to take a closer look at the problem, armed with more and better information than they had at the initial contact. The final exercise contrasts the various opinions and points-of-view expressed in the materials and by the learners themselves. It concludes with a closing round of joint reflection on the discussion and decision-making process among the learners and within society.

The lesson plan

Access to the controversy

The lesson plan opens with a very popular German advertisement for caffeine shampoo, which explicitly describes the product in question as "Doping for your hair." This advertisement has already led to open controversy in society at large. The World Anti-Doping Agency (WADA) in particular has criticized the advertiser for using the word "doping" as if it were a positive or even praiseworthy act. At this point, the teaching unit then expands upon issue by presenting various media reports on sports doping cases found in TV reports and magazine articles. The topic's high media presence helps to reinforce its societal relevance. A question about authority is also raised at this juncture. Thanks to their media presence, most students will know some relevant persons in positions of authority such as politicians. For example, many can name the government minister responsible for sports, including well-known doping experts. Pupils also know about other so-called "authorities" participating in the doping debate like professional athletes, coaches, etc. In

Table 1. Possible topics and activities for learning at stations in the phase clearing up technical questions

Topic	Activity
gas chromatography	explanation of gas chromatography, if necessary aided by a model of the functions of chromatography
mass spectrometry	explanation of mass spectrometry and a thought experiment
spectroscopic methods	explanation of infrared and nuclear magnetic resonance spectroscopy and a matching game with fictitious IR spectrograms
screening tests	model attempt for sample and treatment screening based on chemical indicator reactions
thin layer chromatography	separation of ink using thin layer chromatography in an experiment
paper chromatography	separation of felt-tip pen colors using paper chromatography in an experiment
quick tests	detection of glucose with quick strips

Table 2. Combining subject matter learning with reflecting the limits of doping in a jigsaw classroom

Jigsaw classroom
Group A: Everyday doping – caffeine
Group B: Everyday doping – creatine
Group C: Sanctioned sport doping – EPO
Group D: Sanctioned sport doping – anabolic steroids
Group E: Unconscious doping – ephedrine in cold medicines
Group F: Unconscious doping – nandrolone in food additives

Germany, former national handball player Stefan Kretschmar has repeatedly stated his opinion on doping, often presenting unconventional views of the subject.

Beginning the lesson plan in this fashion leads to a discussion of when doping really begins. It also raises issues such as who can (should be allowed to) define substances as doping agents and who should set the final doping limits. It quickly becomes evident that a cops-and-robbers chase is taking place, in which "doping inventors" are trying to outwit and avoid "doping detectives." All of the above aspects deal directly with chemistry, biochemistry and analytical chemistry, although the latter field is mainly important for setting doping limits. Only detectable doping substances and testable levels thereof can be meaningfully sanctioned by the authorities.

Clarifying the scientific background by practical work

In the next phase, the learning-at-stations method (Eilks, 2002b) is used to examine various analytical strategies and procedures. This allows the learners to understand exactly what analytical chemistry does in general and specifically in the case of doping. The treatment is variable and flexible with respect to subject-matter difficulty and the grade level of the learning group. Our example was designed for grade 10 or 11 (age range 15-17) German chemistry classes. An overview is shown by Table 1. Various approaches (experiments, models and problems), analytical techniques (chromatography and spectroscopy) and strategies (flash tests or screening tests) are covered.

The learning-at-stations phase is combined with a jigsaw puzzle classroom (Eilks, 2005) covering the various types of doping. The different varieties of doping (performance enhancement through everyday components of food, unintentional doping from forbidden substances in medication or food supplements, illegal doping in competitive sports) are connected to well-known substances selected from the doping debate (Table 2).

Resuming the societal debate

After the subject matter learning phase, a reflection occurs on which of the initial issues and questions could be answered with the help of chemistry background knowledge. Questions dealing with what exactly doping is, which substances might be employed, and how analytical chemistry approaches doping measurement become quite clear. What cannot be answered by science are questions about which practices actually constitute doping, whether dopers deserve punishment or not, and how society should handle doping in leisure sport and the fitness arena. Decisions in these areas need to be open to societal debate and spearheaded by societal bodies such as sports associations, the Olympic Committee or the World-Anti-Doping-Agency (WADA).

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