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TRENDS IN WESTERN SCIENCE CURRICULA AND SCIENCE EDUCATION RESEARCH: A BIRD'S EYE VIEW

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Abstract. *The present article starts with a concise report of three important waves of innovation in Western science education, one in the 1960s, one in the 1980s, and one in the 2000s. The background of each wave is concisely explicated in terms of dissatisfaction with the foregoing curriculum and the rise of new general theories on teaching and learning. The reported innovations have influenced the agenda of research in science education in the Western world. In the second part of the article, the main trends in topics and methods of this research are reported. Finally, some main trends in science teacher education are concisely addressed.*

Keywords: *science curriculum innovations, trends, research topics and methods, educational theories, science teacher education.*

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Introduction

The present article deals with main developments in science education and research in science education in the Western world. The aim is to provide the reader a bird's eye view of relevant trends in the last 50 years. This overview does not pretend to be complete, but rather provides the reader the main highlights. The article is an elaborated version of a lecture presented at the third Scandinavian Symposium 'Science teaching for understanding' that has been held at Karlstad University, Sweden, February 2006.

The structure of the article is as follows. First, three main waves of science education reform are addressed. Then, trends in psychological theories of teaching and learning that shaped the innovations are presented. Thereafter, trends in topics and methods of science education research are reported. Finally, trends in science teacher education are concisely addressed.

Trends in Science Curricula

In the last 50 years, several waves of science education reform can be indicated in many countries. I will concisely address three main waves of reform as follows.

An important starting point of the first wave can be located in the middle of the Cold War era, in 1957, when the former Soviet Union launched the first satellite (the

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'Sputnik"), into an orbit around the world. This evoked a shock around the world, and showed the relative inferiority in science and technology in several other big industrialized countries, especially the USA. Educational experts pointed out that one of the main causes of the deficit was the relative low quality of the existing science curricula. They criticized the existing curricula by characterizing them as old-fashioned, overloaded, and mainly facts-oriented. Although this criticism was not very new, the 'Sputnik' effect made the policy makers more willing to listen to it and to invest much more money in the development of new national science curricula. Most of this reform was large-scale, for example, the North-American projects of Chemical Education Materials Study (CHEM Study) and Chemical Bond Approach (CBA), and the British project of Nuffield Chemistry. The leading projects for secondary schools focused on understanding basic concepts and processes instead of knowing a large number of facts, and for that reason, students got the opportunity to use special student data books. The new curricula also focused on stimulating the development of basic scientific skills, and classrooms were adapted or added for conducting laboratory work by students. Although the expectations of the effects of the innovations were high, in general, the results were quite disappointing. For instance, the increase of students' enrolment in first-year university science courses was modest, and many secondary school students continued to complain that the new curriculum content was difficult to understand and not very interesting to them. The failure of these curriculum reforms can be seen to be caused by several factors; one of the main causes concerns the strong focus on the existing 'body of knowledge' of science from the expert perspective, rather than from the student perspective.

Because of the disappointments of the 1960s reform and stimulated by an alarming report from the USA, 'A Nation at Risk', published in 1983, a second wave of curriculum innovations were initiated. In this reform, most projects were smaller scale, for example, the North-American project of 'Chemistry in the Community' (ChemCom), and the British Salters' Chemistry project. In the 1980s reform, the design of most courses was much more focusing on 'active learning' of students, for instance, by introducing (open-) inquiry tasks in the school lab. Moreover, efforts were made to make science much more meaningful to students by relating science concepts and processes to situations from everyday life. Despite all these efforts, the results of this wave of curriculum reform were also quite disappointing. For instance, the enrolment in first-year university science was decreasing, and many secondary school students did not see the relevance of the given contexts for understanding the related concepts and rules.

In order to solve the reported difficulties, about 5-10 years ago, a third wave of innovative science education projects came up. Some examples are the North-American project of 'Chemistry in Contexts: Applying Chemistry to Society' (CiC), and the Dutch project of 'New Chemistry'. At this time, it is too early to evaluate the value of the recent reform properly. Finally, I will note that the interest in computer-assisted instruction and learning came up between the second and third wave of reform, followed by the growing use of Internet in science education.

Trends in Theories that Shaped Science Curricula and Courses

The three waves of science education reform were not only influenced by dissatisfaction with the foregoing curriculum but were also shaped by several new perspectives that came from the domain of educational psychology. I will summarize these perspectives and their main impact on science curricula and courses as follows (see also Table 1).

The first wave of reform (1960s) was strongly guided by two different psychological theories. The first one is often indicated as descriptive behaviourism. This theory focuses on the idea of a stimulus-response mechanism that shapes behaviour by operant conditioning (Skinner, 1953). Learning is considered as something that occurs in a 'closed black box' in each human being; for that reason, only the input side (conditioning) and the output side (learning outcomes) of this 'box' are considered. Because of this perspective, the use of 'programmed instruction' became popular in curricula: series of tasks with direct feedback to answers of individual learners. It also stimulated the introduction of multiple-choice questions in science courses, especially for assessing students' learning outcomes. The second influential psychological theory is often indicated as cognitive development, and focuses on the idea of the development of cognitive stages (sensorimotoric, pre-operational, concrete operational, formal operational) in learners (Piaget, 1954). This perspective had an impact on the sequence of introduction of science topics in science curricula and science textbooks.

The second wave of reform (1980s) was mainly guided by a theory that can be considered as a reaction to descriptive behaviourism as well as a follow-up of the cognitive development perspective. The new psychological theory mainly focuses on the throughput of the 'black box' (that is no longer seen as 'closed'), so, it focuses on the learning process itself. This perspective is generally indicated with the term cognitive psychology and mainly includes the theories of guided discovery learning (Bruner, 1975) and information-processing mechanism of learning (Gagne, 1977). Both theories stimulated the development of science curricula and courses that paid much more attention to creating ways of active learning by students, especially by promoting laboratory work for school students. In line with these perspectives, the instructional strategy of the 'learning cycle' became influential, consisting of the phases of exploration, conceptual invention, and application (Karplus, 1977). Finally, it can be indicated that, in reaction to the use of multiple choice questions, the use of essay questions was promoted. This provided science teachers the possibility for acquiring much more insight in students' learning process.

The last wave of reform (2000s) was strongly guided by two related theories. First, the social constructivist perspective. According to this perspective, learning is a dynamic and social process in which learners actively construct meanings from their actual experiences in connection with their prior understandings and the social setting (Driver, 1989). Knowledge and learning are considered as fundamentally situation based. This point of view stimulated the development of science courses that take much more into account students' authentic ways of reasoning. It also promoted the inclusion of science-technology-society (STS) issues in the curricula, and the interest in the use of contexts that are really meaningful for students. Second, the socio-cultural approach. According to this perspective, education is an enculturation process and learning can be considered as a change from one socio-cultural environment, usual everyday life experiences and knowledge, to a new, scientific environment, including a change of languages (Vygotsky, 1986). This point of view also promoted the introduction of STS issues and meaningful contexts in science curricula and courses, and, moreover, emphasized the importance of using adequate language in textbooks and in the classroom.

Table 1. Science education reform and influential psychological theories.

Wave of reform	Influential theory that shapes curricula and courses	Issue of growing interest
• 1960s	• Descriptive behaviourism • Stages of cognitive development	• Programmed instruction • Sequence of science topics
• 1980s	• Guided discovery learning • Information-processing perspectives	• Lab work for school students • Learning cycle
• 2000s	• Social constructivism • Socio-cultural perspectives	• Students' ways of reasoning • Role of context and language

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Trends in Topics of Science Education Research

In general, trends in science curricula and courses were accompanied by trends in topics of science education research. In this section, I will concisely address several main trends in research topics in the last 50 years.

In the 1960s reform, many science curriculum projects were based on the expertise and opinions of leading natural scientists and science educators who were advised by experts from other educational areas, such as the psychology of teaching and learning. Research in science education did hardly exist at that time. It came up through the reform because there was increasing interest in gathering evidence to establish the effects of the new curriculum projects on students' knowledge and performance. Many other studies were focused on difficulties in teaching new curriculum issues and the use of new teaching strategies, for instance, the use of 'programmed instruction' approaches.

However, in the 1980s reform, new perspectives on teaching and learning caused a shift in the interest of many researchers towards studies of students' alternative conceptions and ways of reasoning. In line with this interest, more and more studies focussed on students' learning process in terms of conceptual change. There was also a growing interest in studies of social and cultural dimensions of knowledge acquirement, for instance, by investigating the discourses between teachers and students in the classroom. Other trends were the growing interest in studies of laboratory work, especially (open-) inquiry, the implementation and use of problem solving strategies, and the use of Internet, computer software, and interactive multimedia.

For getting a more detailed overview of recent trends in research topics, I carried out a content analysis study of three leading research journals in science education for the years 1995 and 2005. The selected journals were: *Journal of Research in Science Teaching* (JRST), *International Journal of Science Education* (IJSE), and *Science Education* (SE). The research topics in both volumes of these journals were classified by using a set of categories that was designed by a step-by-step procedure. First, a list of topic categories was prepared that was based on the list of categories used for structuring the research papers presented at annual conferences of the 'National Association for the Research in Science Teaching' (NARST), and bi-annual conferences of the 'European Science Education Research Association' (ESERA). Second, the combined list was adapted after repeated analysis of the content of both volumes of the journals. Third, categories with scores less than 5% for each of both years were deleted from the list. In this iterative way, a list of 14 categories was developed and used for the final analysis. This list is given below.

- *Students' conceptions* (e.g. about science topics and nature of science)
- *Students' attitudes* (e.g. towards science and learning of science)
- *Students' learning processes* (e.g. learning of science topics and nature of science)
- *Teachers' content knowledge* (CK) (e.g. about science and nature of science)
- *Teachers' pedagogical content knowledge* (PCK) (e.g. about students' difficulties and how to teach science and nature of science)
- *Teaching strategies* (e.g. about use of approaches for teaching science)
- *Developing teachers' CK*
- *Developing teachers' PCK*
- *Practical work* (e.g. aims, formats, student skills, assessment)
- *STS and context-based issues* (e.g. use of everyday life issues)
- *Problem solving* (e.g. about conceptual and computational problems)
- *Models and modeling* (e.g. about use of scientific models and analogies)
- *Information technology* (e.g. use of Internet and interactive computer software)
- *Gender* (e.g. gender-specific patterns in learning)

The results of the analysis are given in Table 2. The table shows that the top three topics in 1995 were: 'Students' conceptions', 'Practical work', and 'Teachers' CK'. In 2005, 'Practical work' is still among the top three, but 'Students' conceptions' and 'Teachers' CK' are replaced by the topics 'Teachers' PCK' and 'STS and context-based issues'. The ranking of the three new top topics increased with at least 1% score in absolute sense. Other topics with increased ranking (with at least 1% score in absolute sense) were: 'Developing teachers' CK', 'Developing teachers' PCK', 'Students' attitudes', 'Models and modeling', and 'Teaching strategies'. Topics with a decreased ranking (with at least 1% score in absolute sense) were: 'Problem solving' and 'Gender'. Topics with a ranking that hardly changed (lesser than 1% score in absolute sense) were: 'Information technology' and 'Students' learning processes'. Finally, I will note that, in general, the ranking of a particular topic depends on the choice of the other categories that are used for analyzing the content of the three journals. So, another list of categories can give another ranking of the topics.

Table 2. Main research topics in three leading journals in science education (JRST, IJSE, SE) for 1995 and 2005.

Category of research topic	Combined scores for 1995 (n = 137)	Combined scores for 2005 (n = 173)
	N/%	N/%
• Students' conceptions	18/13.1	12/6.9
• Students' attitudes	5/3.6	11/6.4
• Students' learning processes	10/7.3	12/6.9
• Teachers' content knowledge (CK)	14/10.2	12/6.9
• Teachers' pedagogical content knowledge (PCK)	10/7.3	21/12.1
• Teaching strategies	10/7.3	15/8.7
• Developing teachers' CK	2/1.5	11/6.3
• Developing teachers' PCK	2/1.5	10/5.8
• Practical work	16/11.7	22/12.7
• STS and context-based issues	12/8.8	17/9.8
• Problem solving	11/8.0	3/1.7
• Models and modeling	9/6.6	14/8.1
• Information technology	9/6.6	11/6.4
• Gender	9/6.6	2/1.2

Trends in Methods of Science Education Research

In general, trends in methods of science education research correspond with trends in methods of research in educational psychology. In this section, I will concisely give a general overview of the main trends in the last 50 years.

Trends in Setting and Design of Research

Initially, many studies were carried out in settings outside school, quite often in psychological laboratories that asked individual students to enact learning tasks about issues that not always were incorporated in the current science curriculum. As a consequence, this research did not provide much insight in the learning of students in realistic teaching-learning situations at school. Regarding the design of research projects, I will note that many of these projects included large-scale studies, most of them mainly quantitative oriented. However, it appeared that much of this research only provided general data with unclear implications for teaching and learning at classroom level.

Later on, the setting of many studies became the classroom itself for getting a better 'ecological validity' of the results of research. Regarding the design of research projects, I will note that a growing number of projects became more small-scale, and often more qualitative ways of collecting

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data were used.

A rising kind of research is indicated as 'design research' (cf. Cobb, Confrey, diSessa,, Lehrer, & Schauble, 2003). It is often related to the cyclic development of new (science) education programmes, and usually investigates differences between expected outcomes of a programme, based on the aims, the underlying framework, and the programme activities, and the real outcomes of a programme.

Trends in Instruments for Research

Initially, many research data were obtained by using quantitative instruments, for instance, multiple-choice questions (cf. Nurrenberg & Robinson, 1994). The use of these instruments was often quite fast and many data could be collected easily. However, data analysis could not provide much information about the argumentation that was used by the students. This kind of information could better be collected in another way, namely by using multiple-choice questions providing students to explicate their answers, and essay questions of an open or a semi-structured nature.

Later on, more other qualitative tools were used, for instance, interviews with students, asking students to draw concepts maps reflecting their knowledge of concepts and mutual relations (cf. Mason, 1992), and inviting students to enact thinking-aloud tasks (cf. Bowen, 1994). The latter kind of tasks includes that students are asked to say what they think when performing a particular task (introspection) or, after finishing a task, to tell what they were thinking during the task (retrospection). Combinations of research instruments were also used, for instance, asking students to design a concept map by thinking-aloud, followed by an interview about the results. The value of all foregoing research instruments is limited because they are not very fruitful for investigating teaching-learning science in their usual context: the classroom or school lab environment itself.

The last years, a new research instrument becomes more and more popular among researchers, namely, classroom protocols (cf. De Jong, 1995). These protocols can be produced by recording (on audio-tape or videotape) discussions of students and teachers in educational situations and transcribing the statements.

For investigating science teachers' knowledge base (CK as well as PCK) and its development, some upcoming research instruments are: (i) the stimulated recall method (Calderhead, 1981), (ii) the story-line method (Beijaard, Van Driel & Verloop, 1999), and (iii) the lesson preparation method (De Jong, 2000). The stimulated recall method includes an interview in which a teacher has to look at a videotape of his/her lesson that has been given shortly before and to explain what he/she thought and did at specific parts of the lesson. This interview technique can be considered as a substitute for the thinking-aloud technique which is not very appropriate because of the interrupting effect in the classroom situation. The story-line method provides information about the teacher's subjective evaluation of his/her knowledge regarding particular aspects of teaching. By drawing a story-line, the teacher describes his/her evaluation, on a scale from positive to negative, as a function of time. He/she is also asked to clarify the main ups and downs in the story-line. Finally, inn the method mentioned last, the teacher has to prepare some lessons about a specified topic but he/she is not allowed to consult any school textbook. In a subsequent interview, the teacher has to explain the written lesson plan and to answer a number of questions, for instance, about his/her knowledge of the curriculum topic, expected students' conceptual difficulties, and intended strategies for teaching the topic.

Trends in Science Teacher Education

The science curriculum reform was also accompanied by innovations of science teacher education. I will concisely address this issue as follows.

In the 1960s reform, an important way for supporting teachers consisted of the introduction of teacher guides. In general, these booklets provided them information about the aims of the innovative curriculum, suggestions for new teaching strategies, lesson schedules, and so on. However, very often, they were hardly used, except for getting hints for demonstrations, suggestions for student practical work, and answers to student exercises. Many teachers felt that the guides did not sufficiently fit their personal needs.

Later on, in the 1980s reform, teacher guides became part of a new approach: teacher course, mainly workshops for groups of teachers. A workshop could cover a couple of hours, a full week (often scheduled as a summer school) or a longer period (spread out in time). These workshops offered the participating teachers an orientation on the new science curriculum topics and the opportunity to discuss their new roles with colleagues. This intended to be a step forwards in supporting teachers, but, in reality, the impact of many workshops was washed out in school practices.

In the 2000s reform, another approach for supporting teachers was introduced: courses that integrate workshops with teaching new curriculum topics in real classrooms. In general, collaborative discussions of teaching experiences were seen as a good opportunity to promote teachers' professional development. Nevertheless, many teachers felt difficulties in adopting new topics and teaching strategies that came from outside their own interest and beyond their usual teaching practice.

Recently, and in line with the former approach, a rising perspective on supporting teachers in the context of curriculum innovations is developed, based on the idea of involving teachers in a much more early stage of reform. This can be realized by inviting teachers to participate in small groups of teachers, teacher educators, and curriculum developers. These groups should function as a learning environment for each of the three stakeholders. In the new created learning community, teachers can fulfil several roles, for instance, co-designers of new materials and teaching strategies, performers of a pilot of the new teaching, and co-evaluators of experiences with the materials and strategies. At this time, it is too early to evaluate the value of this rising approach properly.

Discussion

The present overview indicates a number of important developments in science curricula and research in science education. In the last 50 years, a growing interest in research topics related to students and their learning and teachers and their teaching can be indicated. Recently, an important upcoming research topic is focused on the development of science teachers' knowledge base (cf. De Jong, Veal & Van Driel, 2002). Trends in science curricula and courses will come and go, and 'hot topics' in science education research will rise and fall. So far, so good. However, in my opinion, it is time to pay much more attention to an old issue: the relationship between science education research and science teaching practice. In the last half century, this relationship has been problematic. Several attempts have been made to improve this relationship, for instance, by publishing a growing number of books that would inform and support the practice of science teaching (see e.g. De Jong, Kortland, Waarlo & Buddingh', 1999; Monk & Osborne, 2000). Nevertheless, for many years, researchers have also pointed out the poor effects of their efforts; for example, they complain that the outcomes of research often do not find their ways into the practice of teaching of science (Shymansky & Kyle, 1992). On the other hand, practising science teachers consider personal experiences, common sense, and official documents as much more important sources of their professional knowledge than results of research (Costa, Marques & Kempa, 2000). In conclusion, one of the biggest challenges of the near future of science education is to bridge the gap between science education research outcomes and science teaching practices in the classroom.

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ОБЗОР ТЕНДЕНЦИЙ РАЗВЫТИЯ ОБРАЗОВАТЕЛЬНЫХ ПРОГРАММ В ЗАПАДНОМ ЕСТЕСВЕННО-НАУЧНОМ ОБРАЗОВАНИИ

Онно Де Йонг

Статья начинается с краткого обзора трёх значимых волн инноваций в Западном естественно-научном образовании, имеющих место в периодах времени около 1960, 1980 и 2000 годов. Основой соответсвующих волн инноваций являлось неудовлетворение со существующими образовательными программами и появление новых общих теорий обучения. Сообщаемые инновации соответственно отразились на порядок проведения научных исследований в области естественно-научного образования. Последующее содержание статьи знакомит с основными тенденциями развития тематики и методов этих исследований. В заключении кратко характеризованы основные тенденции развития подготовки учителей естественно-научных предметов.

Ключевые слова: инновации программ естественно-научного образования, тенденции, тематика и методы исследований, теории образования, подготовка учителей естественно-научных предметов.

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