

# CHEMISTRY TEACHERS AS STAKEHOLDERS OF NATIONAL CONTEXT-BASED CURRICULUM REFORM PROJECT

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**Abstract** The present paper deals with a national curriculum reform project on modular context-based chemistry teaching in the Netherlands. A main characteristic of the project is the use of a 'bottom-up' approach for designing the 'New Chemistry' curriculum. A document analysis of project-related reports and empirical studies was carried out. The results showed that chemistry teachers were involved in all phases of the project: analyzing current problems, preparing outlines for renewal, developing context-based modules, and testing a pilot version of the curriculum. Some modular learning pathways were composed as exemplar tools for supporting teachers. Results at the end of the curriculum project showed that positive opinions about modular context-based teaching were expressed by about half of the interviewed teacher-innovators and about one-third of the teacher-followers. Nevertheless, negative opinions were expressed by an important minority of teachers. Implications for empowering teachers for modular context-based chemistry education are discussed.

**Keywords:** Chemistry curriculum reform, context-based teaching, modular learning pathways, teachers as curriculum stakeholders

## 1 Introduction

In the past 50 years, three important waves of chemistry education reform for secondary schools can be identified: the 1960s wave, the 1980s wave, and the 1990s/2000s wave.

In the 1960s wave, leading renewal projects were the USA project 'Chemical Bond Approach' (Strong, 1964), and the UK project 'Nuffield Chemistry' (Halliwell, 1966). These projects were influenced in large part by chemists themselves and, for that reason, were academically rather rigorous. In the 1980s wave, important innovations were introduced by the USA project 'Chemistry in the Community' (ChemCom) (ACS, 1988), and the UK project 'Chemistry: The Salters Approach' (UYSEG, 1989). These projects were mainly influenced by teams in which chemists cooperated with other experts, not only general education specialists but also school chemistry teachers. For instance, in the ChemCom project, teachers and university professors participated in writing context-based, student-centred learning materials. In the 1990s/2000s wave, several new curricula projects were launched with a strong focus on ways to enlarge chemistry teachers' commitment to innovations. Examples of these projects are the UK project 'Salters Advanced Chemistry' (SAC project, 1994), the German project 'Chemie im Kontext' (ChiK) (Gräsel et al., 2005), the Israelian project 'Industrial chemistry and school chemistry' (Hofstein & Kesner, 2006), and the Dutch project 'New Chemistry' (Apotheker et al., 2010). The latter project, which has the status of a national curriculum reform project, is the focus of the present paper.

## 2 The 'New Chemistry' curriculum project

### 2.1 Main phases of the project

The 'New Chemistry' curriculum project was established in 2002 by the Dutch Ministry of Education, Culture, and Science. Several other important stakeholders were also involved in the project, such as the Netherlands Institute for Curriculum Development (SLO), the Association of Dutch Chemical Industries, the Dutch Association for Science Education, university chemistry departments, and, last but not least, chemistry teachers.

The project aimed at designing a complete new curriculum for secondary schools including context-based modules that were related to contemporary chemistry, societal challenging issues, and students' interests. The structure of the project consisted of four main phases:

- i. Analyzing problems regarding the current curriculum (2002),
- ii. Preparing outlines for renewal (2003),
- iii. Elaborating a context-based modular curriculum (2004-2010),
- iv. Evaluating 'New Chemistry', esp. a pilot version of the curriculum (2007-2010).

The project came to an end in 2010. The project results were offered to the Ministry and accepted by this department in 2011. The first national final chemistry examination based on this curriculum will take place in 2015. At that time, it will be possible to evaluate the complete curriculum properly.

### 2.2 Core issues and questions regarding the project

The present paper does not focus on the 2013 implementation of the new curriculum but addresses some specific issues related to the foregoing phases of the curriculum reform project.

Firstly, the issue of chemistry teachers' participation. The enactment of the project was a complex process, especially because of the decision to apply a 'bottom-up' approach for designing the 'New Chemistry' curriculum. This required the participation of teachers in each of the phases of the project; their involvement varied from phase to phase.

Secondly, the issue of learning pathways as teaching tools. The main product of the project consisted of a context-based chemistry curriculum that prescribed new chemistry learning aims and topics (the 'what' issue). However, it did not prescribe how these topics should be taught (the 'how' issue). Nevertheless, to support teachers, teaching options consisting of the use of different modular learning pathways were also proposed.

Thirdly, the issue of chemistry teachers' opinions. At the end of the project, teachers were asked to indicate their opinions about the context-based modular approach and a pilot version of the curriculum. Their answers provided additional information about the 'New Chemistry' curriculum.

These issues are elaborated by presenting answers to the following questions:

1. In what ways were chemistry teachers involved in each of the phases of the 'New Chemistry' project?
2. What modular learning pathways options were proposed for supporting chemistry teachers' use of context-based modules?
3. What opinions did chemistry teachers express about 'New Chemistry' at the end of the project?

Answers to these questions were obtained by a document analysis of project-related reports and relevant empirical studies. These documents and the results of the analyses are specified in the sections below. The order of these sections corresponds with the order of the project phases mentioned above.

### 3 Teachers and the phase of problem analysis

In the problem analysis phase, an Exploratory Committee on Chemistry Education was established by the Dutch Ministry in the spring of 2002. This committee should examine problems regarding the current chemistry curriculum. In order to collect data, the committee interviewed 52 representatives of the stakeholders, among them 11 chemistry teachers (that is 21% teacher participation). In their final report (Van Koten, et al., 2002), the committee indicated several general problems, such as the image of the chemistry discipline is quite negative, school chemistry does not intrinsically motivate students, and measures to improve the quality of chemistry education are weak. Specific problems with regard to chemistry teachers were also reported. A summary of these problems is given in Table 1.

The Exploratory Committee recommended to draw up a new vision on chemistry education in terms of an outline of a new chemistry curriculum. Regarding the development of this curriculum, the committee recommended to involve teachers in this process and to look for those teachers who are really interested in new developments and are willing to contribute. These teachers could function as inspiring beacons for their less interested colleagues.

Table 1. Reported problems concerning chemistry teachers

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- \* Teachers' task demands are increasing,
  - \* Teachers' professional development is decreasing,
  - \* Teachers are tired of changes in education.
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### 4 Teachers and the phase of outlines for renewal

In this phase of the project, a Renewal Committee on Chemistry Education was established by the Dutch Ministry in the autumn of 2002. This committee should sketch outlines of the desired nature and content of a new chemistry curriculum. The committee should also look for possible solutions for the problems that have been reported by the foregoing committee. In order to perform these tasks, the committee organized group discussion meetings with 159 representatives of the stakeholders, among them 90 chemistry teachers (that is 57% teacher

participation). In their final report (Driessen & Meinema, 2003), the committee recommended to incorporate chemistry content that is understandable for all students, not only for students who focus on chemistry related careers. The new curriculum should include contemporary chemistry and societal challenges. It should also adopt a context-concept approach (De Jong & Taber, 2014). Regarding chemistry teachers, the report also presented a number of recommendations. A summary is given in Table 2.

The Renewal Committee recommended to use the presented outlines as guidelines for designing a context-based chemistry curriculum. Obviously, the committee preferred a 'bottom-up' approach of curriculum reform.

Table 2. Recommendations regarding chemistry teachers

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* Teachers should develop context-based modules in small teacher teams, guided by a coach; each team is part of a larger regional teacher network,
* Teacher should test the modules in classrooms and discuss the results for revision purposes,
* Teachers should get curriculum options that fit their personal conceptions of chemistry teaching and learning.

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## 5 Teachers and the phase of context-based modular elaborations

In this phase of the project, a Steering Committee on New Chemistry was established by the Dutch Ministry in the spring of 2004. This committee should elaborate a context-based chemistry curriculum design by using the outlines that have been reported by the foregoing committee. Moreover, a pilot project should be launched for investigating the quality of a pilot version of the complete curriculum when used in a limited number of senior secondary schools. In order to carry out these tasks, the committee initiated a broad range of activities in which teachers were often involved. In their final report (Apotheker et al., 2010), the committee presented the main teacher activities and roles. They can be summarized as follows.

In the project, small teams of chemistry teachers from 5-8 schools designed one or more context-based modules. Each team was guided by a coach, often a teacher educator, and was part of a larger regional network for exchanging experiences. The drafts of the modules were tested in classrooms by the teacher-designers or other teachers. The results were reported and discussed in the designing teams for revision purposes. In this way, the teams functioned as 'communities of learning'. It is well-known that such communities provide a context that motivates teachers for professional learning and supports them when they are involved in curriculum innovations (Connelly & Clandinin, 1988).

Teacher-designers and field testers can be considered as *innovators* in the curriculum process. Some other groups of teachers also acted as innovators. An overview of all groups of innovators is given in Table 3. Beside these innovators, there were groups of teachers that can be considered as *followers*. An overview of these groups is given in Table 4.

Table 3. Chemistry teachers as innovators in the curriculum process

<b>Role of teacher as innovator schools**</b>	<b>Participating</b>
* Designer of context-based modules schools	180 schools
* User of context-based modules without a field testing role	31 schools
* Participant of the pilot project on teaching the complete curriculum	19 schools
* Member of subcommittees for supporting activities	20 schools

\*\* Each school delivered one or more teachers (number not given in the committee's report)

Table 4. Chemistry teachers as followers in the curriculum process

<b>Role of teacher as follower**</b>	<b>Participating schools</b>
* Visitor of conferences and workshops	about 250 schools
* Visitor of protected parts of the project website (password)	about 150 schools
* Visitor of open access parts of the project website	unknown number
* Reader of 'New Chemistry' articles in teacher journals	unknown number

\*\* Each school delivered one or more teachers (number not given in the committee's report)

## 6 An example of a 'New Chemistry' module

Nearly 60 context-based modules were designed by the teachers. Each module consisted of a student booklet, a teacher guide, and often a booklet of resources. Some modules are available in Dutch at the free access project website:

[www.nieuwescheikunde.nl/Publicaties/Lesmodulen](http://www.nieuwescheikunde.nl/Publicaties/Lesmodulen). All other modules could only be entered at protected links of the project website by using a password. All suggested modules were intended to function as examples of teaching and learning 'New Chemistry'. Teachers were free to adopt the modules, to adapt them, or to replace them by other materials.

The modules were often structured by using an slightly adapted version of a format taken from the German 'Chemie im Kontext' (ChiK) project (Gräsel et al., 2005). This version consisted of four main phases and a pre-phase. An elaboration of these phases is given below for the module 'Rescuing diapers in case of fire' for students of grade 10 (age 16). This module (about 10 lessons) can be found under the Dutch name 'Reddende luiers' at the free access project website mentioned before.

The pre-phase regards the orientation to the module. Students were concisely informed about the name of the module, the general learning goals, and the main instructional format. They also got a student booklet and a resource booklet about rescuing diapers.

Phase 1 regards the introduction to the context. Students were told that a fireman has found from his practice that disposable diapers are effective fire-resistant materials. The leading context question of the module was: how to prepare a fire-resistant means from disposal constituents. The introductory activity consisted of some practical experiments in the school lab, such as cutting a disposable diaper into pieces for drawing the content parts, and to investigate the maximum water absorption capacity of a new diaper.

Phase 2 regards the selection of specific questions. Students were asked to discuss the results of their practical work and to look for explanations. They were also asked to discuss

what they wanted to know about fire-resistant characteristics of diapers, how they might find answers to their questions, and to plan possible activities.

Phase 3 regards the development of new knowledge. Students were asked to work on a series of practical assignments. For instance, an activity dealt with preparing mixtures of water and a number of different materials/substances, followed by investigating the fire-resistance of the mixtures. Another activity consisted of investigating the difference in water absorption of wool, cotton, and diaper-polymer. Students were also asked to prepare jelly mixtures of water and diaper-polymer grains, water and wall paper powder, and water and algae powder, followed by investigating their viscosity and discussing the suitability of the mixtures as fire-resistant material. Some other assignments regarded simulations of structures by modeling. For instance, students were asked to string several chains of beads, to create networks of these chains by making crosslinks, and to compare the results with electron microscopic pictures of fibres of wool, cotton, and diaper-polymer. Subsequently, they were asked to discuss the specific relation between the crosslink structures on the one hand and the jelly properties (viscosity) and water absorption capacity properties on the other hand. In the resource booklet, students could find relevant formation such as: (i) the macro-concepts of absorption, hydrophilic and hydrophobic phenomena, (ii) the meso-concepts of fibre structures and networks, and (iii) the micro-concepts of polymer particles and crosslinks (H-bridges). The overall concept was also presented: the relationship between structures and properties. Near the end of this phase, students were asked to look at sustainable fire-resistant means made from natural ingredients. For that reason they were suggested to prepare and investigate mixtures of solutions of algae powder and solutions of  $\text{CaCl}_2$  in different concentrations. Finally, students were asked to answer the leading context question.

Phase 4 regards the *abstraction and transfer of knowledge*. Each group of students was asked to write a summarizing evidence-based report on their work in terms of macro, meso, and micro features of structure-property relations. Each group was also asked to present their report to other students and to address possible applications.

Finally, some 'New Chemistry' modules were translated into English by a special foundation and were available at other free access sites. For instance the module 'Green chemistry' (energy balances, atom economy, process chemistry) is available at: [www.studioscheikunde.nl/havovwo\\_bb/Module\\_Green\\_Chemistry/](http://www.studioscheikunde.nl/havovwo_bb/Module_Green_Chemistry/). Another example is the module 'How can we eat healthily' (carbohydrates, fats, proteins) can be found at: [www.studioscheikunde.nl/havovwo\\_bb/Module\\_How\\_can\\_we\\_eat\\_healthily/](http://www.studioscheikunde.nl/havovwo_bb/Module_How_can_we_eat_healthily/).

## 7 Modular teaching/learning pathways

In order to facilitate students' learning, the Steering Committee (Apotheker et al., 2010) suggested to cluster modules in pairs in which chemistry concepts were introduced and elaborated in successive contexts. Each pair of modules would be followed by a bridge module in which the chemical concepts were further abstracted from the contexts and new questions

could be addressed. An example of such a short teaching/learning pathway (string) is given in Table 5.

Table 5. Example of a short teaching/learning pathway

<b>Module</b>	<b>Leading context question</b>	<b>Major concept</b>
Eco-travelling: The trip	How to calculate the most sustainable trip of 30 days around the world ?	Introductory organic chemistry. Mole. Molar mass. Molar volume. Stoichiometric calculations. Sustainability.
Eco-travelling: The fuel	How to produce biofuels?	Follow-up organic chemistry. Bonding. Calculations of reaction energy. Biofuels.
Bridge module	What do we have learnt?	Concept maps. Exercises. New questions.

Based on the recommendation from the Renewal Committee, the Steering Committee decided to develop a curriculum that offers teachers the opportunity to use longer teaching/learning pathways, for instance covering a full school year. These pathways should fit teachers' personal conceptions of chemistry teaching and learning. This decision of the committee required information about these conceptions among chemistry teachers. Relevant information could be acquired from a study carried out by Van Driel et al. (2005). They investigated conceptions about teaching and learning at a representative sample of 348 chemistry teachers who represented about one-third of the entire target group. A written questionnaire was used for focusing on content-related ideas about the chemistry curriculum. From the analysis of the answers, three clusters of conceptions in terms of curriculum perspectives were distinguished. The first cluster was related to the curriculum perspective of 'Fundamental Chemistry' (FC). The second cluster was related to the curriculum perspective of 'Chemistry, Technology, and Society' (CTS). The third cluster was related to the curriculum perspective of 'Knowledge development in Chemistry' (KDC).

The preference for the FC perspective was stronger than the preference for each of the two other perspectives, while the CTS perspective was more preferred than the KDC perspective. The researchers concluded that the preference for FC might be explained as a result of the teachers' commitment in the present curriculum, which many of them had taught for a long time. Regarding the preferences for CTS and KDC, they suggested to consider them as important input for the designing of the new chemistry curriculum.

Table 6. Three categories of teaching/learning pathways

<p><b>* 'Chemistry, Technology, and Society' (CTS) teaching/ learning pathway</b>            This pathway fits conceptions of teachers who are interested in teaching chemistry from the perspective of the role of chemistry in everyday life and society.</p>
<p><b>* 'Knowledge Development in Chemistry' (KDC) teaching/learning pathway</b>            This pathway fits conceptions of teachers who are interested in teaching from the perspective of chemistry as an empirical scientific discipline</p>
<p><b>* Mixed CTS/KDC learning pathway</b>            This pathway fits conceptions of teachers who want to combine CTS modules with KDC modules.</p>

The Steering Committee used the reported information about teachers' conceptions of chemistry teaching and learning for composing and elaborating three categories of teaching/learning pathways of related modules. A concise overview of these categories is given in Table 6. The committee suggested the following example of a CTS teaching/learning pathway for a full school year: a string of two modules on new materials, two modules on sustainability (see Table 5), two modules on chemistry of life, and, finally, two modules on chemistry technology. Examples of long teaching/learning pathways from both other categories can be found at the website of the project. All suggested pathways should function as examples of possible teaching strategies. They were not prescribed but could be used.

## 8 Teachers and the phase of evaluation

In this phase of the project, an Evaluation Committee was established by the Dutch Ministry in 2007. Chemistry teachers' opinions about a pilot version of the complete curriculum were investigated in the period 2007-2010 by Ottevanger et al. (2011). They interviewed about 25 participating teachers (their number varied somewhat per school year) by using a written questionnaire. Relevant results are summarized in Table 7.

Table 7. Chemistry teachers' opinions about the pilot curriculum

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### **Opinions of the feasible aspect**

- \* Most of the teachers indicated that the curriculum was overloaded: the context-concept approach required a lot of time and sufficient time for practical work was not available,
- \* About three-quarter of the teachers had the opinion that the intended implementation of the definite curriculum in 2013 is desirable, and somewhat more than half of them thought that it is feasible,

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### **Opinions of the teachable aspect**

- \* The teachers appreciated the context-concept approach more and more, mainly because of the possibility to use contexts related to societal issues and students' everyday life,
- \* A majority of the teachers thought that the chemistry concept-related differences between the old and new curriculum are not very big.

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### **Opinions of the testable aspect**

- \* According to the teachers, the testing of students' knowledge of chemistry concepts should occur in the framework of contexts,
  - \* Nearly three-quarter of the teachers was satisfied about the students' achievements.
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At the end of the project, another Evaluation Committee was established by the Association of Dutch Chemical Industries. Chemistry teachers' opinions about the idea of the context-based modular approach were investigated by Van der Woude and Van Grinsven (2010) by using an online questionnaire. The collected answers came from a representative sample of 302 teachers of which 45% can be classified as innovators, that is, teachers who had designed, tested, or used one or more modules and 55% as followers, that is, teachers who had no experience with using any modules. Relevant results are summarized in Table 8.

**Table 8.** Chemistry teachers' opinions about the context-based modular approach\*

Topic of opinion	Chemistry teachers' opinion			
	Innovators (n=135)		Followers (n=167)	
	Pos.	Neg.	Pos.	Neg.
* The context-concept approach	53%	24%	35%	35%
* Any modular approach	51%	29%	34%	38%
* Used or seen modules	55%	26%	31%	35%
* Downloading modules from project website	72%	15%	58%	28%

\* Percentages of neutral opinions are not given here

## 9 Conclusions and discussion

Regarding the question *in what ways chemistry teachers were involved in each of the phases of the 'New Chemistry' project*, the results of the document analysis showed that they participated actively in all phases of the project in a variety of ways. Firstly, as informers of problems with the current curriculum. Secondly, as participants of discussion meetings about possible outlines for renewal. Thirdly, as innovators and followers in the phase of designing the new curriculum. Finally, as field testers of a pilot version of the curriculum. This teacher participation covered about a several hundreds of chemistry teachers. This is about one-third of the entire target group. Although the number of participating teachers is not very large, it is large enough to provide the new curriculum a firm base of evidence. Moreover, the participating teachers can consider themselves as co-owners of the curriculum reform.

Regarding the question *what modular learning pathways options were proposed for supporting chemistry teachers' use of context-based modules*, the analysis results indicated that the three learning pathways took teachers' conceptions of teaching chemistry into account. This could contribute to increase the acceptance and feelings of co-ownership of the new curriculum among chemistry teachers. Teachers were supposed to express their preference for a particular learning pathway. This could stimulate them to become more aware of their teaching conception and to reflect on them.

Regarding the question *what opinions chemistry teachers did express about 'New Chemistry' at the end of the project*, the results of the document analysis indicated some interesting opinions among teachers. First of all, most teachers from the pilot project indicated that the new curriculum was overloaded because the context-concept approach required a lot of time and sufficient time for practical work was not available. However, with regard to the current curriculum, chemistry teachers already have complained about the growth of their task demands. So, the 'New Chemistry' project was not very successful in solving the problem of relieving teachers' tasks. Secondly, the teachers from the pilot project appreciated the context-concept approach more and more during the project, mainly because of the possibility to use contexts related to societal issues and students' everyday life. Thirdly,

regarding opinions of modular context-based teaching, about half of the online interviewed innovators and about one-third of the followers indicated positive opinions. Nevertheless, negative opinions were expressed by an important minority of teachers. The latter result is somewhat surprising because the modular approach in terms of three learning pathways was based on the evidence-based presence of three clusters of teachers' preferred curricular conceptions.

In conclusion, the answers to the three questions emphasize the necessity to support chemistry teachers for context-based teaching. This is not only relevant for teachers who were not involved in the curriculum project but also for project teachers. From the pilot curriculum project, about two-third of the teachers appeared to feel a need for further professional development (Ottevanger et al. (2011). Regarding the possible content of this development, Van der Woude and Van Grinsven (2010) found that the highest interest among the 302 online interviewed teachers' concerned learning more about modern contexts, followed by their interest for learning more about ways of organizing student learning activities.

There are several ways for chemistry teachers to learn about context-based teaching, for instance by visiting relevant conferences and workshops, by participating in small (regional) networks of interested colleagues, and by reading relevant articles in journals such as the online journal *Chemistry Education Research and Practice* (free access [www.rsc.org/ceerp](http://www.rsc.org/ceerp)). The continuous professional development of chemistry teachers, supported by adequate research, will function as an important cornerstone of the further reform of chemistry curricula in the near future (Van Driel & De Jong, 2015). This is not only valid for the Netherlands but also for many other countries which are involved in context-based chemistry curriculum reform.

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