Essential Characteristics for a Professional Development Program for Promoting the Implementation of a Multidisciplinary Science Module

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Abstract Teachers involved in the implementation of a curriculum innovation can be prepared for this task through a professional development program. In this paper, we describe essential characteristics (identified empirically and theoretically) for such a professional development program that promotes the acquisition of competences by these teachers. The innovation deals with the introduction of modules from a new multidisciplinary subject, in which elements from physics, chemistry, biology, mathematics, and physical geography are integrated. A 3-step approach was used to identify the essential characteristics: (a) evidence from classroom practice, (b) characteristics of the new subject, and (c) theoretical and empirical evidence from curriculum implementation studies. Analysis of the data showed that 5 characteristics need particular attention in a professional development program.

Keywords Professional development program · Implementation · New curriculum · Teacher involvement · Multidisciplinary subject

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Introduction

The success of the implementation of a new curriculum at the secondary school level depends among other factors on the active involvement of teachers in the curriculum design process, their feeling of ownership of this curriculum, and the further preparation by these teachers (Hargreaves 1994; Rousseau 2004; Wikeley 2005). Implementing a new subject that can be considered a curricular innovation means that teachers have to be introduced to the new subject domain, have to understand the elements of the innovation, have to adopt the innovation, and have to acquire the new knowledge, skills, and routines needed to adequately teach the new subject (Bergen and Van Veen 2004; Shulman 1987; Van den Akker 1999). This may be achieved by means of a professional development program in which teachers are actively involved (Garet et al. 2001; Loucks-Horsley et al. 2003; Penuel et al. 2007). Such a program can take various forms: (a) workshops and seminars, (b) teacher communities that carry out research and design activities, and (c) work with professionals experienced in both the domain and in teaching. Active teacher participation in a professional development program influences the quality of the lessons and eventually students’ achievements (Fishman et al. 2003).

Professional development programs are often only designed on the basis of characteristics described in research literature. Less focus and analysis is specifically devoted to the creation of a professional development program where the starting point begins with the school practice. A successful implementation is more likely when a professional development program is consistent with this practice (Hill and Cohen 2005; Waslander 2007). Therefore, the characteristics of the professional development program have to be connected to the everyday school practice of individual teachers, if not the result is a gap between the program and practice.

In this study, we focus on identifying essential characteristics of such a program to support teachers involved in the introduction and implementation of a new multidisciplinary science module in their classroom. The essential characteristics identified can later be used to design a suitable professional development program consistent with the school practice.

The new science subject dealt with in this article is called Advanced Science, Mathematics and Technology (ASMaT), and was introduced in the science curriculum of the upper level of secondary education in the Netherlands in August 2007. ASMaT is a multidisciplinary subject, integrating elements from physics, chemistry, biology, mathematics, and physical geography, and has a modular structure. Objectives for introducing this subject in the school curriculum are as follows: (a) it enables students to become familiar with a wide range of higher education options and professions; (b) it lets students experience the importance of interdisciplinary coherence in the development of science and technology; (c) it creates a closer connection between science education and new developments in society, science, and technology; and (d) it encourages cooperation with higher education and research institutes.

The multidisciplinarity of the subject requires schoolteachers from different science departments (physics, chemistry, biology, mathematics, and physical geography) to cooperate in a multidisciplinary team in order to implement this
new subject. The implementation of ASMaT at the school level has several specific features. Firstly, teachers involved in the teaching of ASMaT have a degree in one of the mono-disciplinary subjects listed above, but have not been specifically trained for this new multidisciplinary subject. Secondly, the multidisciplinary team of teachers has the freedom to select the modules, and the order in which the modules will be taught. Thirdly, the team of teachers also decides which and how many teachers will be teaching a specific module. By selecting a particular module, not only is the topic and the content determined, but also to a large extent the teaching methods and the assessment strategies and tools. Because teacher teams make different choices, implementation varies from school to school.

The essential characteristics of a professional development program to support ASMaT teachers in developing expertise in specific fields for an effective implementation of an ASMaT module will be identified in a three-step approach. First an evidence-based approach in school contexts to identify implementation characteristics from existing classroom practices is employed. Secondly, specific features of the subject ASMaT are used. Finally, the third step consists of evidence from the curriculum implementation literature.

To begin with, the research questions will be explained followed by the conceptual framework in which this three-step approach will be explained.

Research Questions

This study aims to theoretically and empirically identify essential characteristics for a professional development program that promotes the acquisition of teachers’ competences involved in the implementation of an ASMaT module. The general research question is “Which characteristics are essential for a professional development program to promote the implementation of an ASMaT module?” Three specific sub-questions are distinguished: (a) Which characteristics are important during the selection of an ASMaT module according to the “evidence-based” approach? (b) Which of these characteristics from the first sub-question belong to what kind of professionality? (c) Which characteristics from the second sub-question stimulate the implementation of an ASMaT module according to teachers and according to the curriculum implementation literature?

Conceptual Framework

The ‘Evidence-based’ Approach

Connecting the characteristics of the professional development program to the everyday school practice, teachers’ prior knowledge, beliefs, and skills must be taken into account in order to make a professional development program successful (Davis 2003; Lieberman 1995; Schwab 1973). Professional development programs should also be adjusted to the diversity of behaviors and beliefs of their participants.
(Cotton 2006; Luft 2001), and should support the professional growth as the outcome of a complex process (Clarke and Hollingsworth 2002).

Two aspects are of vital importance when thinking in terms of class implementation of implementing an innovation that takes into account the school’s practice: (a) the curriculum design phases and (b) the curriculum components. A framework based on these two aspects is used to collect and organize the implementation characteristics. The curriculum design phases are based on the general process components of a generic model for curriculum design (Marsh and Willis 2003; Verhagen et al. 1999; Visscher-Voerman 1999; Visscher-Voerman and Gustafson 2004). The curriculum components have their roots in the curricular “spider web” proposed by Van den Akker (2003).

The generic model that reflects the process of designing a curricular innovation has been applied to the ASMaT module, resulting in the following five phases. Firstly, the “Module Selection” phase—teachers have the freedom to determine which modules will be offered, in line with the modular structure of the ASMaT subject. During this selection phase, teachers select the module they are going to teach. Secondly, the “Module Preparation” phase—this encompasses all the steps before the module is actually delivered, such as drawing up a study program for students, dividing tasks among teachers, and trying-out experiments. Thirdly, the “Module Teaching” phase—this phase focuses on the teaching and actual classroom delivery, for example on changes made in the study program, the teaching methods used, and the cooperation between teachers. Fourthly, the “Effect of the Module” phase—this shows the degree to which goals are achieved after finishing the module. The fifth and final phase is “Reflection on the Module.” In this phase, the teacher reflects on the module to determine strong aspects and elements that need to be adapted (See the columns in Table 1).

The curriculum components we used are based on the need for creating balance and consistency between the various curriculum components. Van den Akker (2003) proposed a framework of ten components addressing ten specific questions about the planning of student learning. He visualized these ten curriculum components as a spider’s web, not only to illustrate the numerous interconnections, but also to underline its vulnerability.

As this study is about the teachers’ implementation of an ASMaT module in the classroom, for pragmatic reasons the ten curricular components were reduced to

| Curriculum components | Curriculum design phases |
|-----------------------|--------------------------|
|                       | Module selection | Module preparation | Module teaching | Effect of the module | Reflection on the module |
| 1. Aim                |                       |                     |                  |                      |
| 2. Content            |                       |                     |                  |                      |
| 3. Pedagogy           |                       |                     |                  |                      |
| 4. Conditions         |                       |                     |                  |                      |
| 5. Assessment         |                       |                     |                  |                      |

Table 1 Five-by-five curriculum components and design matrix

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five: aim, content, pedagogy, conditions, and assessment (See the rows in Table 1). ‘Aim’ is used to describe the rationale, aims, and objectives of a module. ‘Content’ describes what is actually taught in class. ‘Pedagogy’ is about learning activities, materials and resources, the teacher’s role, and student grouping. ‘Conditions’ encompass location and time, and ‘Assessment’ refers to both learning progress and learning outcomes.

Combining the five curriculum design phases and the five curriculum components leads to a five-by-five matrix (Table 1). As this matrix covers all the main strategic elements that are relevant to curriculum implementation, it will be used as the data-organizing instrument to present the evidence from the interviews focusing on the implementation in schools.

The ASMaT Subject

ASMaT is a new optional science subject that was introduced in upper secondary education in the Netherlands in August 2007. Schools interested in offering ASMaT had to register at the National Steering Committee responsible for this subject. While ASMaT is different from other traditional science subjects, it is linked to them at the same time. The ASMaT curriculum is different because it is based on contexts and has a modular structure. A teaching module consists of a situated practice (for example, using forensic technology, MP3-players, or holography) in which specific concepts traditionally belonging to physics, chemistry, biology, mathematics, and physical geography are explored. Through its interdisciplinary character, the content of the ASMaT modules goes beyond the sum of the contents of the traditional science subjects. Teachers usually have a degree in one of the traditional science subjects. Therefore, teaching the ASMaT modules is challenging, because the modules not only deal with their own disciplines, but also involve content from other science disciplines at a high level. The advantage of the modular structure is that schools have more freedom in offering this subject. It gives teachers the opportunity to select modules according to their interests and expertise and to their students’ interests and prior knowledge. In order to encourage schools to offer high quality education in this new subject, the National Steering Committee has formulated a number of criteria that schools should fulfill to become an officially registered implementation school. A criterion that schools have to fulfill is selecting the modules following the examination program. The ASMaT examination program consists of nine different domains. The following examples illustrate this. The domain “Biomedical technology and biotechnology” is about developments in biomedical technology and biotechnology. Modules in this domain that schools can choose from are for instance “Technical design in biomedical technology,” “Food and fuel,” and “Artificial kidney and membranes.” A different domain is called “Language of science” where students learn to use relevant concepts and techniques from mathematics and/or computer science and apply these on science or technological issues. Modules that cover this domain are “Dynamic models,” “Make the difference,” and “Measuring and interpreting.”

Another important criterion is that a team of teachers consisting of at least three teachers with different master’s degrees (physics, chemistry, biology, mathematics,
or physical geography) should be responsible for teaching ASMaT (Steering committee ASMaT 2007).

As described earlier, ASMaT is a subject with several specific features. Therefore, ASMaT teachers implementing this subject must possess a broad knowledge base and good classroom skills. Hoyle and John (1995) made a distinction between what they termed as restricted professionality and extended professionality. In restricted professionality, the focus is on teachers’ own classroom practice. Extended professionality refers to a broader range of knowledge and skills, going beyond the individual classroom. Extended professionality is largely acquired through participation in a wide range of professional development activities, including attending in-service courses, reading professional literature, visiting other institutions, and collaborating with colleagues. ASMaT is a broad, interdisciplinary subject in which teachers have to collaborate with each other in school, research institutes, and industry, in a sustainable manner. For students, a team of teachers is an example of interdisciplinary collaboration among subject experts. Contacts beyond school enable students to become familiar with a wide range of higher education options and professions. Therefore, a professional development program for ASMaT must promote the extended professionality of the teachers. The distinction of Hoyle and John (1995) will be taken into account when analyzing the characteristics developed for the professional development program.

Research about Effective Implementation

A completed matrix, as shown in Table 1, contains the implementation characteristics for an ASMaT module for a particular school: the choices made by the teachers and their considerations. To determine which characteristics need to be covered by a professional development program, the elements for effective implementation as identified in research are relevant. In the process of curriculum implementation, many aspects play a role that can be either stimulating or hindering. Factors influencing the implementation of a curriculum can be categorized into four areas (Fig. 1; Van den Akker 1998). Each area will be briefly explained below.

![Fig. 1 Categories influencing implementation (from Van den Akker 1998)](image)
Curriculum Intentions

During the introduction of a new subject, teachers will especially find support from specific student learning material (Desimone 2002; Van den Akker 1998; Waslander 2007). The learning material largely determines the content, knowledge, and skills students acquire at school. The quality and the usability of the learning material therefore are important for teachers and students alike. Learning materials guide teachers in their teaching but this does not mean that teachers use the materials exactly as the developers had in mind. Teachers adapt and supplement learning materials to their own situation and needs, and this promotes ownership. Teacher ownership is necessary to change teacher’s routines in order to try something new (Bergen and Van Veen 2004). Several studies show that teachers’ sense of ownership is a stimulating condition for implementation (Ogborn 2002; Wikeley 2005). There are indications that teachers’ sense of ownership contributes to higher student achievement (Caprara et al. 2006).

Curriculum Effects

Curriculum effects include student experiences and learning outcomes. Student characteristics such as capacity and motivation determine curriculum implementation effectiveness and learning outcomes (Lepper et al. 2005). Contextual variables such as the home situation, media, and friends also affect student achievement through informal learning (Van den Akker 1998).

Context

The context includes policy, school organization, and external support for the curriculum. Policy entails the decisions about testing programs and the attainment targets for the subject. Cooperation between teachers and coordination within departments are part of the school organization. Collaboration between colleagues is a stimulating condition for the implementation of an innovation. Usually teachers only cooperate with colleagues in their own departments (Van Wessum 1997). Multidisciplinary collaboration can provide motivation and introduce teachers to a broader variety of ideas and teaching methods (Leliveld et al. 2008; Meirink 2007). Teachers can assist colleagues by sharing information and experiences whereby new knowledge can be developed (Ball and Cohen 1996). The teachers who implement the innovation must be given time and feel supported by the school management (Geijssel et al. 2001; Wikeley 2005). The external support includes collaborative activities between colleagues in the same school and between schools. This can be stimulated in a professional development program (Andrews and Lewis 2002; Desimone 2002; Waslander 2007).

Teacher Characteristics

Various studies report and discuss the important role that teachers play in the implementation (Fullan 2007; Geijssel et al. 2001; Kwakman 2003). Teachers’
knowledge and beliefs are determined by their education and experiences. Beliefs about what is feasible and valuable for their students, preferences for certain teacher roles, and preferences for teaching methods will influence any implementation (Beijaard et al. 2004; Pajares 1992; Van den Akker 1998; Van Veen and Sleegers 2006).

Methods

Participants

A written invitation to participate in this research was sent to thirteen teachers at thirteen different officially registered implementation schools in the eastern part of the Netherlands. One teacher did not respond at all, while four teachers had not yet started implementing ASMaT modules; the remaining eight teachers all participated in this study. All participating teachers were heads of their ASMaT departments and active ASMaT teachers. Three were chemistry teachers, two biology teachers, two physics teachers, and one mathematics teacher. Six of the participants were male and two female. All had more than 6 years’ teaching experience.

The eight schools that participated in this study were among the first schools to implement the subject ASMaT and started teaching ASMaT modules in August 2007. They developed their own strategies for implementation without assistance or examples from other schools.

Data Collection Instruments

To investigate the implementation process of an ASMaT module in the school we used semi-structured interviews in which teacher have to take the last module taught in mind. For each cell of the five-by-five matrix shown in Table 1 a question was formulated. Table 2 shows the designation of the different cells in Table 1 and an example of the answers we found for the question formulated for cell 1: For which aim was the module selected? This question involved a combination of the first

| Curriculum components | Curriculum design phases | Module selection | Module preparation | Module teaching | Effect of the module | Reflection on the module |
|------------------------|--------------------------|------------------|-------------------|----------------|---------------------|-------------------------|
| 1. Aim                 |                          | Cell 1           | Cell 6            | Cell 11        |                     |                         |
|                        |                          | Student interest |                   |                |                     |                         |
|                        |                          | Feasibility      |                   |                |                     |                         |
| 2. Content             |                          | Cell 2           | Cell 7            |                | Cell 12             |                         |
| 3. Pedagogy            |                          | Cell 3           | Cell 8            |                | Etc.                |                         |
| 4. Conditions          |                          | Cell 4           | Cell 9            |                |                     |                         |
| 5. Assessment          |                          | Cell 5           | Cell 10           |                |                     |                         |
curriculum component (Aim) and the first curriculum design phase (Module Selection). With a completed matrix, we had an overview of how an ASMaT module was implemented in a specific school. After these 25 questions, the following open question was phrased: What is stimulating and what is hindering you during the implementation of an ASMaT module? This question provided additional information about what teachers experienced as stimulating or hindering aspects during the implementation.

Procedure

The first author of this article conducted a semi-structured interview with each of the eight participants who had started teaching ASMaT from the beginning of the school year 2007–2008. The semi-structured interviews were conducted between January and April 2008. All interviews took place in a location chosen by the teacher (e.g., the teacher’s classroom or a small office) and the conversation was recorded. Each interview took about 40 min. All the interviews were transcribed. The transcripts were returned to the teachers for verification and approval. In these transcripts, the core elements of the answers were identified and translated into keywords. For example, an answer given by a teacher in cell 1 (For which aim was the module selected?) was “We selected our module because we thought it would interest our students and we assessed the feasibility of the module”. The keywords for this answer were ‘student interest’ and ‘feasibility’ (See Table 2, cell 1). Quite often multiple keywords were identified and included in the matrix. Each cell was populated in this way.

Analysis

In this section, we discuss how the research data were analyzed (a) to describe important characteristics during selection (Research Sub-question 1), (b) to classify characteristics into kinds of professionality (Research Sub-question 2), and (c) to indicate stimulating characteristics for implementation (Research Sub-question 3). The flow of the study is visualized in Fig. 2.

Research Sub-Question 1: Important Characteristics during Selection

The eight matrices from the different schools were combined into one new matrix. For instance, all the keywords in cell 1 from the eight matrices were aggregated in one new cell 1 of the new matrix. The keywords of the open question: “What is stimulating and what is hindering you during the implementation of an ASMaT module?” were also added. The resulting matrix was very comprehensive with many keywords.

To ensure the reliability of the keywords, a researcher not previously involved in this research was asked to check whether the keywords represented the key points of the sentences and whether these were consistently used for similar fragments. This resulted in 86% immediate agreement; the other findings were discussed until a consensus was reached.
To answer research question one, cells 1 to 5 were needed. Similar keywords from these cells were collapsed. The important keywords are therefore mentioned twice or more, or were also mentioned in the additional question. These important remaining keywords were transformed back to the original sentences as answered by the teacher as accurately as possible. We call these characteristics.

Research Question 2: Classification of Characteristics into Kinds of Professionality

The first two curriculum design phases (Module Selection and Preparation) from the original five curriculum design phases occurred before the actual implementation of an ASMaT module. The third and fourth curriculum design phases (Module Teaching and Effect of the module) took place during the implementation. The last curriculum design phase (Reflection on the module) occurred after the implementation. Therefore, the five curriculum design phases were collapsed into three curriculum design phases: one phase before, one during, and one after implementation.

Similar characteristics from these cells were collapsed. Characteristics mentioned less than twice were removed unless they were also mentioned as stimulating or hindering in the additional question. The characteristics of this three-by-five matrix were classified according to Hoyle and John (1995), into the restricted professionality characteristics (e.g., focus on classroom practices) and the extended professionality characteristics (e.g., cooperation with colleagues) where similar characteristics were clustered. While doing this it became clear that some characteristics (those with comments about the quality of the module, for instance) did not fit these two classes.
For these characteristics, we created a third group, namely “neither restricted nor extended professionality.”

Research Question 3: Stimulating Characteristics for Implementation

In this sub-question only the stimulating characteristics from sub-question 2 were used. Stimulating characteristics are identified from the answer of the open question after the semi-structured interview and were also mentioned in the semi-structured interview. These stimulating characteristics were compared with research literature findings about elements for effective implementation. When a stimulating characteristic according to the teachers also was found in literature for effective implementation, this characteristic becomes a stimulating characteristic for implementation; if not it was eliminated.

Results

Important Characteristics during Selection

The implementation process of a new ASMaT module into classroom practice consists of different phases. The first phase is the “Module Selection” phase, important because of the modular structure of ASMaT. In this phase, teachers have the freedom to determine which modules they are going to teach. They may base their decision on the content, the teaching methods, assessment, or some combination of these.

The characteristics that teachers mentioned as needing attention in the selection of a module are shown in the left column of Table 3. These characteristics were deduced from the results in the first column of Table 2 of the semi-structured interview. The semi-structured interview ended with the open question: “What is stimulating and what is hindering you during the implementation of an ASMaT module?” The results from this question are reported in the right column of Table 3. The teachers’ answers were related to both students and teachers; this division is shown in the rows of Table 3. An answer one teacher gave was “I feel enthusiastic when I notice the coherence between different mono-disciplines in an ASMaT module. For example in the topic EAR, biology and physics are related very well. When I notice this I am excited to teach it to my students.”

Classification of Characteristics into Kinds of Professionality

The characteristics of the three-by-five matrix were classified into three groups based on Hoyle and John (1995): the restricted professionality, the extended professionality, and the “neither restricted nor extended professionality” group. The characteristics are shown in Table 4. Teachers’ intentions with respect to these characteristics are explained below. The characteristics under A to E and O to R are mentioned both in the semi-structured interview and during the open question after the interview (“What is stimulating and what is hindering you during the
A to E were mentioned as a stimulating characteristic during implementation; O to R were mentioned as hindering. Some teacher statements included:

- It is very stimulating to experience other knowledge, outside the regular daily program in my own classroom. I also learn things from other subjects. Beside that, the cooperation with the university and research institutes is meaningful and stimulating too (Open Question, Teacher 1).
- The cooperation with other teachers is very stimulating and necessary for successfully implementing ASMaT (Open Question, Teacher 1).
- When I am well prepared for the lessons I have to teach, the lessons are going better and it feels stimulating (Open Question, Teacher 2).

Below we explain the characteristics from the restricted professionality group:

- **Modules’ appropriateness.** Teachers find it stimulating when the content connects to students’ prior knowledge and when the module is attractive and interesting for students.
- **Teachers’ preparedness.** Teachers want to prepare and organize their lessons extensively but often time is a limiting factor. Teachers find it stimulating when after intensive preparation they experience that everything ran smoothly.
- **Teachers’ ownership.** Teachers prefer curricular innovations in which they have freedom to follow their own preferences. Selecting and adapting teaching material to suit their situation and needs promotes teachers’ ownership.

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**Table 3** Characteristics That According to the Teachers Need Attention During the Selection of an ASMaT Module

| Characteristics that were mentioned during the interview | Characteristics that were both mentioned during the semi-structured interview and during the open question after the semi-structured interview |
|----------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------|
| Related to students | The module should: | The module should fit: |
| The module should: | Connect to students’ prior knowledge | The interest of the students |
| Offer sufficient in-depth knowledge | Broaden the knowledge of students | Permit students to work independently with it |
| Be correct, clear, and structured | Provide variation in skills and pedagogy | |
| Show interrelationships between content of the mono-disciplines | Have a social meaning and prepare students for follow-up studies | |
| Have a social meaning and prepare students for follow-up studies | |
| Related to teachers | The module should: | The module should: |
| The module should: | Have some freedom to include (creative) suggestions from the teacher | Fit the interest and knowledge of the teacher |
| Be realisable and practicable for the teacher | Have a social meaning and prepare students for follow-up studies | Include materials and facilities that are easy to achieve |
| Have a social meaning and prepare students for follow-up studies | | Have a good teacher’s guide |
ASMaT is a multidisciplinary subject having a modular structure; the content of the ASMaT modules goes beyond the more traditional science subjects (physics, chemistry, biology, mathematics, and physical geography). ASMaT teachers have a degree in one of the science subjects and naturally prefer to teach content related to their subject.

Pedagogy. The teachers prefer to use various teaching methods (e.g., individual work, student group work), practicals (e.g., practical demonstrations, student research), and assessment methods (e.g., portfolios, presentations).

Evaluation and reflection. Teachers want to evaluate and reflect on each module in their own class, but there is not always enough time for this.

Teachers’ assistance. Teachers prefer the availability of a good teachers’ guide of the module as this can provide guidance and answers to questions. The availability of an experienced lab technician saves teachers’ time as a lab technician can prepare and perform trial lessons.

Student independent work. Teachers find it important that the module provides sufficient guidance in class for students to work independently so they do not need teacher assistance all the time. When students often need help, teachers experience this as a hindering aspect.

Below we explain the characteristics from the “neither restricted nor extended professionality” group:

### Table 4 Stimulating and Hindering Characteristics Categorized in Three Groups of Professionality (Hoyle and John 1995)

| Restricted professionality | Neither restricted nor extended professionality | Extended professionality |
|---------------------------|-----------------------------------------------|-------------------------|
| Stimulating<sup>a</sup>   |                                               |                         |
| A Modules’ appropriateness|                                               | C Knowledge acquisition by teachers |
| B Teachers’ preparedness  |                                               | D Teachers’ cooperation  |
| Neutral<sup>b</sup>       |                                               | E Teachers’ networking |
| F Teachers’ ownership     | K Student achievement                         | L Teachers’ competences  |
| G Link up to teachers’ prior knowledge |                     | M Evaluation |
| H Pedagogy                |                                               | N Mono-disciplinary coherence |
| I Evaluation and reflection|                                               |                         |
| J Teachers’ assistance    |                                               |                         |
| Hindering<sup>c</sup>     |                                               |                         |
| O Student independent work| P Responsibility National Steering Committee  |                         |
|                           | Q Modules’ suitability                         |                         |
|                           | R School facilities                            |                         |

<sup>a</sup> Stimulating: Mentioned as a stimulating characteristic, answered in the open question after the semi-structured interview and also mentioned in the semi-structured interview

<sup>b</sup> Neutral: These characteristics were not mentioned in the open question after the semi-structured interview but only during the semi-structured interview

<sup>c</sup> Hindering: Mentioned as a hindering characteristic, mentioned in the open question after the semi-structured interview and also in the semi-structured interview
• **Student achievement.** Student motivation and learning results were lower than teachers had initially anticipated and hoped for.

• **Responsibility National Steering Committee.** When teachers experience problems preparing or teaching a module, they want to get assistance. If the National Steering Committee does not respond quickly to questions that teachers have, teachers experience this as a *hindering* aspect.

• **Modules’ suitability.** Teachers find it *hindering* when the ASMaT module does not have the correct size, when the structure is not clear, or when there are inaccuracies in the content.

• **School facilities.** Teachers find it *hindering* when equipment and materials needed to teach a module (e.g., computers) are not sufficiently available at school. Teachers want to prepare their lessons in cooperation with colleagues and the school organization therefore must be flexible with respect to timetable requests such as parallel scheduling, block scheduling, and collective consultations with colleagues.

Explanation of the characteristics from the extended professionality group

• **Knowledge acquisition by teachers.** Teachers find it *stimulating* when they acquire new knowledge in the form of science content, instruction, and assessment methods. This knowledge can be obtained by consulting colleagues, experts, and literature.

• **Teachers’ cooperation.** Teachers find it motivating and *stimulating* to work with colleagues from different disciplines. They learn from each other by discussing ideas, teaching methods, and content. When team-teaching a module with colleagues from different subjects, teachers can assist each other and share information and experiences.

• **Teachers’ networking.** Teachers find it *stimulating* when they participate in a well-organized network meeting where teachers from different schools participate in collaborative activities.

• **Teachers’ competences.** Teachers think that not every teacher makes a good ASMaT teacher. The ASMaT teacher should have qualities such as a broad interest in science, broad employability, being socially competent with students, and a willingness to spend time and energy on the new subject.

• **Evaluation.** Teachers not only find it important to evaluate and reflect on each module in their own classroom (see I), but also appreciate evaluation and reflection in collaboration with colleagues.

• **Mono-disciplinary coherence.** Students and teachers experience and create coherence between the mono-disciplines because of the integrated character of the ASMaT module.

Research Question 3: Stimulating Characteristics for Implementation

The results from research question 2 are characteristics classified into three groups. The characteristics in the first row from Table 4, A to E are experienced as *stimulating* by the teachers. The characteristics in the last row, O to R were experienced as *hindering.*
Characteristics that *stimulate* implementation of an ASMaT module should be incorporated into a professional development program. *Hindering* characteristics should be neutralized or avoided wherever possible. The question that now arises is: are the *stimulating* characteristics that teachers mentioned also described in the literature?

The characteristic “Modules’ appropriateness (A)” can be linked to the category “Curriculum effect” of Van den Akker (1998). Capacity and motivation of the students are two aspects that influence the effectiveness of curriculum implementation. When students study a module in which the content links to their prior knowledge, and they experience the module as both pleasant and interesting, it will promote the implementation. The characteristic “Teachers’ preparedness (B)” can be found in “Teacher characteristics”. Teachers’ knowledge, skills, attitudes, experiences, preferences for teacher roles, and teaching methods all influence the effectiveness of the implementation (Beijaard et al. 2004; Pajares 1992; Van den Akker 1998; Van Veen and Sleegers 2006). For example, when a teacher has positive experiences with a situation, and this situation turns out to be part of the module, the implementation will be stimulated. The characteristic “Knowledge acquisition by teachers (C)” and “Teachers’ cooperation (D)” can be linked to the category “Context” from Van den Akker (1998). Cooperation between colleagues is a stimulating condition for implementation of an innovation, especially in multidisciplinary collaboration. It can provide motivation and introduce teachers to a broad variety of ideas and teaching methods (Leliveld et al. 2008; Meirink 2007). Teachers can assist colleagues by sharing information and experiences through which new knowledge can be developed (Ball and Cohen 1996). The characteristic “Teachers’ networking (E)” is also linked to the category “Context” from Van den Akker (1998). Collaborative activities in which teachers from different schools participate are effective strategies for teacher learning (Andrews and Lewis 2002; Desimone 2002) and teacher learning is important for successful implementation.

All the stimulating characteristics from the evidence-based approach, shown in the first row of Table 4, are also considered to be stimulating according to the curriculum implementation literature.

**Conclusion**

Professional development programs are often designed only on the basis of characteristics described in research literature. Taking school practice as a starting point to the creation of a professional development program, a successful implementation is more likely (Hill and Cohen 2005; Waslander 2007). Effectively implementing a new multidisciplinary subject such as ASMaT is in particular a complex endeavor, because teachers do not have specific prior training for this new subject, and they are not familiar with cooperating with colleagues from other science disciplines. In order to prepare teachers adequately for ASMaT it is essential to set up a professional development program. This study focused on the identification of characteristics for such a program. The general research question in this research was as follows: “Which characteristics are crucial for a professional development program to promote the implementation of an ASMaT module?”
In this study we discussed the empirical basis for a professional development program directed towards the implementation of new multidisciplinary modules in secondary education in the Netherlands. We identified and investigated a three-step approach. The first step was evidence produced in the classroom settings of the schools. Teachers were interviewed about the procedure followed and the decisions made to implement a module in their school, and the adaptations made to tailor the module to their particular classroom setting. As a second step, specific curriculum features of the ASMaT subject were taken into account. Hoyle and John (1995) and relevant national curriculum documents were used to analyze and categorize the information from the teachers interviewed. The third step consisted of evidence generated by curriculum implementation literature pertaining to effective characteristics of implementing an innovation. These three steps approached the problem of identifying the essential characteristics for a professional development program from different angles. We started with teachers and their practices in order to develop the characteristics of the professional development program, connected these characteristics to the features of ASMaT, and linked them up to what has been described as successful curriculum implementation in the research literature. The combination of these three steps can be regarded as an effective and efficient method of triangulation, resulting in a number of systematically obtained characteristics for a professional development program.

The answers to the three sub-research questions filled a database with possible ingredients for a professional development program. The first sub-question was about selecting an appropriate ASMaT module. Teachers mentioned selection characteristics that were related to students and to teachers. Students’ prior knowledge, their interest and motivation, and the instructional strategy used, were considered important. Practical issues pertaining to teachers—the quality and availability of materials, and teachers’ interest in the topic—surfaced. Five characteristics were mentioned during the semi-structured interview and again during the open question after the semi-structured interview, and are therefore considered especially important when selecting a module. These characteristics are as follows: (a) the module should fit the interest of the students; (b) the module should permit students to work independently of a teacher; (c) the module should connect to the knowledge and interest of the teacher; and (d) the module should include materials and facilities that are easy to obtain; and the module should have a high-quality teacher’s guide.

The answer to the second sub-research question contains characteristics from the existing school practice related to the professional features of ASMaT. The characteristics were classified into three groups based on the work of Hoyle and John (1995): (a) the restricted professionality, (b) the extended professionality, and (c) the “neither restricted nor extended professionality” group. Extended professionality refers to knowledge and skills going beyond the individual classroom. For a subject like ASMaT, with its multidisciplinary nature requiring teachers from different subjects to collaborate, the characteristics of the extended professionality group are therefore considered especially important when it comes to the implementation of an ASMaT module.

To answer our third sub-question, characteristics stimulating implementation were distilled from the existing school practice and these were compared to the
curriculum implementation literature. The stimulating characteristics found in our study were also described as stimulating in literature.

A professional development program like the one this study suggests and we aim to design needs to incorporate characteristics that stimulate implementation and avoid ones that hinder it. For instance, the hindering characteristics “student independent work” and “modules’ suitability” can be avoided by incorporating a session in the professional development program in which participants can adapt and supplement the module.

Three characteristics stimulate implementation and belong to the extended professionality group. These are considered of special importance for a professional development program. These three characteristics are as follows: knowledge acquisition by teachers, teachers’ cooperation, and teachers’ networking. Two other characteristics—”Modules’ appropriateness” and “Teachers’ preparedness”—are also considered stimulating and important for each curriculum, (Desimone 2002; Van den Akker 1998; Waslander 2007) and are therefore also taken into account. Five characteristics that address the general research question were, this way, identified as essential characteristics that should be incorporated into a professional development program to promote the implementation of an ASMaT module. In the actual design of the professional development program, these essential characteristics can be interpreted as follows:

- **Teachers should develop their knowledge.** Teachers should be given ample opportunities to acquire new knowledge and skills, for example science content, instructional strategies, and assessment methods. Experts, colleagues, and specific literature can provide this knowledge.

- **Teachers should cooperate with colleagues.** Teachers should first be given opportunities to exchange and discuss experiences and ideas with colleagues. Discussion topics can be teaching methods and content, but also practical issues such as how to use a specific activity in class. Cooperation can be intensified by having teachers develop additional material or assessment instruments.

- **Teachers should network.** The result of the professional development program should be a well-organized network in which teachers from different schools participate in collaborative activities.

- The module should be made relevant and attractive for students. Teachers can design stimulating curricular elements to increase students’ interest and motivation.

- **Teachers should be well prepared and organized for their lessons.** In the professional development program, teaching and learning difficulties can be discussed, and good practices exchanged. How to prepare practical activities and where to obtain certain equipment and materials also needs to be addressed.

**Limitations and Implications for Further Research**

The five characteristics as described above are important for the design of the professional development program for those teachers. A limiting factor is that the
numbers of teachers is relatively small and are mainly based at schools in the eastern part of the Netherlands. In addition, further study is needed to evaluate whether the five essential characteristics are a suitable starting point for the design of a professional development program for ASMaT-teacher, for promoting the implementation of an ASMaT-module. To answer this question a research approach used by McKenney et al. (2006) can be used. The evaluation should focus on the learning process and the attained outcomes. The results of that evaluation can provide a better understanding of the theoretical perspectives for an effective professional development programs for teachers, implementing a multidisciplinary-module.

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