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A Conceptual Framework for Cross-Curricular Teaching

Astrid Beckmann

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SPECIAL ISSUE ON INTERDISCIPLINARY TEACHING

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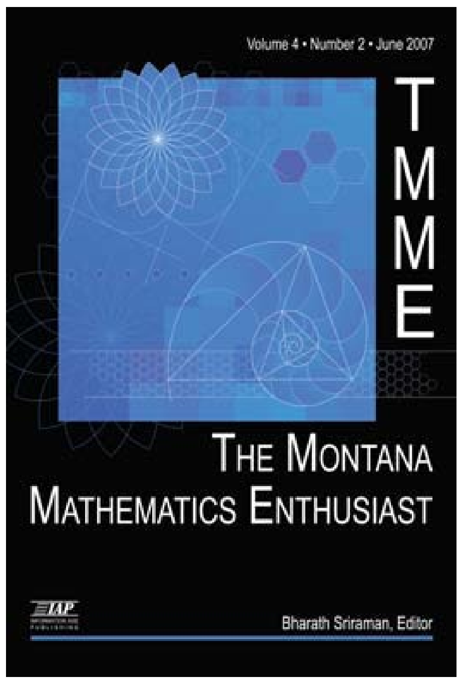

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Preface to special issue

The Montana Mathematics Enthusiast is pleased to present a special supplemental issue this year focused on the issue of interdisciplinarity in the curriculum and classroom. This book is based on the longitudinal research carried out by Prof. Astrid Beckmann of the University of Education, Schwäbisch Gmünd- Germany, who is one of the co-founders of the Mathematics and its Connections to the Arts and Sciences international group (MACAS).

In the USA, several models of connected and integrated mathematics curriculum have been implemented as well as evaluated. However, in spite of a proliferation of modeling and cross-disciplinary oriented curricula, there seems to be a lack of a specific conceptual framework for teaching. It is a misnomer to think that applied problems within the mathematics curriculum such as the solving real-life problems that deal with finding of the most efficient use of resources for a manufacturing company, or optimization problems involving scheduling and routing necessarily provide "transfer" opportunities to other real-world situations involving chemistry, scheduling of services, financial business, and ecology. It requires a concentrated effort on the part of the teacher and the learners, often involving the co-operation of teachers that teach other subjects in order to take a specific learning situation and make it truly interdisciplinary in nature. In the dominant school practices in the United States inter-disciplinarity is seen more as an exception, which is often challenged by the so-called 'traditionalists' who regard interdisciplinary learning as a loss of integrity and thematic curriculum as 'squishy' (Ferrero, 2006). Recent policy level changes in the U.S signal a shift back to traditional curricula focussing on arithmetic and algebra. In Canada, the transition in the school reform movement between the 20th and 21st centuries was marked with more explicit emphasis on more integrative school curricula.

As my colleague, Viktor Freiman mentions, in the province of New Brunswick, the French schools go even beyond it putting a common K-12 theoretical framework for all school subjects which prioritizes the development of a new learning culture of 'learning to learn', making sense of learning, getting equilibrium between individual engagement and collaborative work in an ***interdisciplinary learning environment***. Interesting results regarding interdisciplinary connections have been obtained in numerous studies conducted by members of the MACAS group such as the successful integration of literature, art and mathematics in the high school curricula ; physics and mathematics; paradoxes and mathematics; and an analysis of polymathic traits of students in interdisciplinary problem situations (see Beckmann, 2007 a, b; Beckmann & Sriraman, 2007; Sriraman & Adrian, 2004,a,b; Sriraman, 2003, 2004a,b 2005, 2007a,b).

Data from projects such as the New Brunswick Laptop Initiative show how technology can be an agent of change in the classroom learning and teaching culture when interdisciplinary problem based scenarios are used to track the process of use of science, mathematics and language art to solve a real-world problems (Freiman, et al., 2007). Another experience also related to technology is a creation of a virtual interdisciplinary interactive collaborative learning community of problem solvers in math, science, and French called CASMI which only after one year of existence has attracted more than 5000 schoolchildren, university students, and teachers (Freiman, Lirette-Pitre, and Manuel, 2007).

From psychological and educational points of view there are many arguments for interdisciplinarity. Interdisciplinarity enables more connections to existing knowledge and thus leads to more complex and integrated learning. Interdiscplinarity allows more student centered lessons and increases motivation. It can also nourish reflection on specific methods of the own subject and to understand its importance. At higher educational levels, research argues for the need of so called interdisciplinary conversations that may provide a fruitful new area of exploration involving broader patterns invisible from a strictly disciplinary view (Dalke, Grobstein, & McCormack, 2006). Dalke et al., also suggest that the most generative exchange between individuals occurs as a reciprocal loop between the metaphoric relations of one individual and the metonymic structures of another, such interplay shifts perpetually generating new questions and new understandings.

From its historical and cultural development, the heritage of mathematics reveals itself as a highly connected field of study. Recognition and use of connectivity among mathematical ideas, understanding how to build interconnected mathematical ideas into a whole, as well as capacity of their applications in different contexts outside of mathematics are now seen as core competence of every mathematically educated individual. In this vein, many educational systems in Canada and worldwide are implementing a more integrated and real- life connected mathematics curricula. Beyond these curricular statements, we see the utopian goal to create a humanistic approach of education, one that unifies various strands of the curricula as opposed to dividing it (Beckmann, Michelsen, Sriraman, 2005; Sriraman & Dahl, 2009). How can schooling create well-rounded individuals akin to the great thinkers of the Renaissance (Italian, Islamic)? That is, individuals who are able to pursue multiple fields of research and appreciate both the aesthetic and structural/ scientific connections between the arts and the sciences. The history of model building in science conveys epistemological awareness of domain limitations. Arts imagine possibilities, science attempts to generate models to test possibilities, mathematics serves as the tool (Sriraman, 2005). The implications for education today is to move away from the post Renaissance snobbery rampant within individual disciplines at the school and university levels. By building bridges today between disciplines, the greatest benefactors are today's gifted children, the potential innovators of tomorrow (Sriraman & Dahl, 2009). I am hopeful that the work of the MACAS group will become more and more systemic by creating new collaborations; conducting new studies; reflecting on commonalities and differences – for multidisciplinary, multicultural and divergent approaches to mathematics and its teaching and learning. Astrid Beckmann provides a useful and practical conceptual framework via which such a discourse can take place.

Bharath Sriraman
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A Conceptual Framework for Cross-Curricular Teaching

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1 Preface

The need for cross-curricular[1] teaching has become more prevalent in recent years. There exists a rising intensity in the recommendations of school curricula and policy documents of the federal states in Germany, such as subject-related recommendations, in frameworks of the educational policies issued by the ministries and in the general didactical debate. There are numerous publications in which the specialized content of two or more subjects are integrated into a single proposal for a lesson plan. The starting point of such lessons are as a rule, subject specific content matter. Any thoughts about intertwining didactic concepts are more an exception than the rule here. So far, there has been no comprehensive theoretical backup[2].

This publication aims to fill this gap by developing a Conceptual framework/model for Cross-Curricular / Subject- Integrative Teaching. The term model in this context is to be understood in a pedagogical sense as a theory that analyzes didactic action on a general plane and describes it through paradigms. Like all didactic models it has a “heuristic function” (Gudjons 1999, p.235) in that it opens up certain problem areas and makes them the subject of discussions (i.e.: What factors of cross-curricular teaching are enriching and which factors are problematic?). On the other hand, it is related to “practical designing and planning, pedagogical action, concrete layouting, the evaluation of and the responsibility for teaching” (Gudjon 1999, p.236). The present model is to be understood as designed to enable teachers to make informed decisions in concrete situations by naming the single components of cross-curricular teaching on the basis of general didactic models as well as subject related considerations and teaching concepts.

In section 2 a model of cross-curricular / subject-integrative teaching is presented and definitions of terms are formulated. In section 3 the theoretical framework is extended by providing rationale for cross-curricular teaching based on concrete objectives.

[1] The term cross-curricular used in this book can be taken to be synonymous with the term inter-disciplinary

[2] The existing concepts of cross-curricular teaching refer at best to singular aspects (Cf.2)

2 A Model for Cross-curricular / subject-integrative Teaching

2.1 Initial Definition of Terms

The following serve as initial working definitions:

First, cross-curricular teaching is a specific form of instruction. That is, we are talking about teaching, i.e. concerning ourselves with content, a method, a way of thinking - in general with a topic. Second, the term cross-curricular implies the existence of clearly defined subjects, disciplines. All pupils know about the existence of such subjects from their own experience. In chapter 2 we concern ourselves with aspects of constructing a canon of subjects. Third, the term cross-curricular implies the possibility that we go beyond a subject, i.e. that we cross disciplinary boundaries and in the process we touch on something else. This will by necessity be something outside the respective subject and, at least partially, something taken from different subjects.

This leads us to a first general definition:
Cross-curricular teaching is instruction within a field in which subject boundaries are crossed and other subjects are integrated into the teaching (how and for whatever purpose or objective).

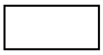
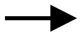
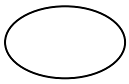
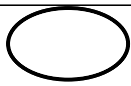
On a scientific level this crossing of boundaries is made concrete through two terms:
Trans-disciplinariness is the extension of one's own discipline to another field of work, whereas "inter-disciplinariness is the co-operation of various related subject areas" (Arber 1993, p.11). This is a very important distinction, and one that is often confused in the literature.

In this context, inter-disciplinariness means the bilateral or multilateral co-operation of various disciplines, while trans-disciplinariness means the creation of a new organizational framework (Fried, Eizendörfer 2000, p.16). The distinction points to the fact that different forms of co-operation and organization are possible within cross-curricular scientific work. The following paper aims to show that this is also true with regard to school work and that cross-curricular means and describes a very heterogeneous phenomenon.

2.2 Organization

Cross-curricular teaching means the extension to other subjects or the integration of these into one's own subject. Therefore, successful work requires that there is a proficient co-operation with other subjects. An individual can only achieve this through some proficiency in multiple subjects. As a rule of thumb, this can occur though, co-operation with specialists, such as teachers in the relevant subjects.

Given these considerations cross-curricular teaching implies the co-operation of various subject teachers.

The starting points of any co-operation are the subjects or subject areas.	
Alternatively, an accepted main subject.	
Cross-curricular work requires initiative,	
which leads to a feedback (one also talks of contributory work (IPTS).	
This may be expressed by a continuous exchange.	
If the initiatives come from two subjects the exchange is even more intensive.	
The exchange may be so intensive that it is expressed in constant joint work.	
The central topic may be subject related and may appear as a topic common to many subjects;	Topic
It may, however, also lie outside one subject and/or relate to the content of many subjects.	Topic
The lesson planning[3] can be done by individual subject teachers or by the team as a whole. It may relate primarily to one subject or to various subjects at the same time. The ellipsis in the graph indicates the respective planning area.	
The total planning may be characterized by intensive exchanges.	

[3] Planning is here meant as a comprehensive term and refers to the continuous planning of lessons, i.e. to the reflections and preparatory work as well as spontaneous decisions before or after the lessons, course or project.

The forms of co-operation can be very different. In its simplest form, it may be restricted to subject related co-operation, enriching the individual subjects involved mutually; it may, however, also mean joint planning of the content, the objectives and methods, the examples or courses of instruction; and can also be expressed in joint project work.

In the following model each co-operation is composed of characteristic elements. The different types of co-operation develop out of the combination of these elements. Each element is marked by a symbol.

More specifically:

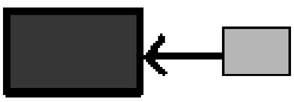
2.2.1 Forms of Co-operation

The various forms of co-operation result from the combination of the co-operation elements. The rise in level goes together with an increase in the intensity and the complexity of co-operation and the subject. For example, Levels 1 and 2 characterize the fact that the work goes beyond one individual subject, while at levels 3 and 4 co-operation is based on the joint work of the subjects.

In the following the various forms of co-operation are marked by their basic structures. These basic structures can be extended through the participation of other subjects.

Cross-curricular Teaching

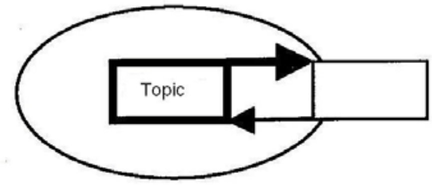
Level 1:
Topic- and Major Subject-Related Form (TM-Form)



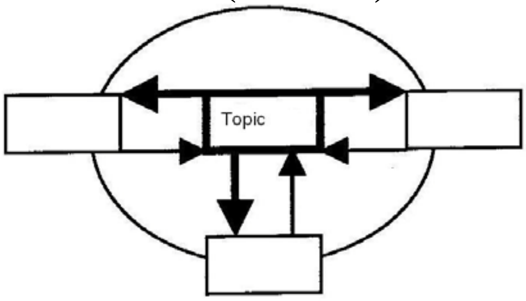
The co-operation starts with the teacher's realization that the teaching needs to go beyond the subject/disciplinary boundaries and that the content and methods of other subjects need to be used. The colleagues from other departments are involved by providing complementary aspects that consolidate the major or central subject. The area of planning only extends to certain elements of the other subject or subjects.

We speak of a special case if the teacher, who teaches in a cross-curricular way, has a multiple competence.

Basic structure



Extension (extendable)

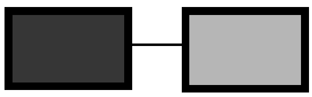


Note:

In the present model, the term cross-curricular teaching is quite extended/flexible: it is given level 1 standard, although the planning does not involve the co-operating subjects entirely. From a pedagogical point of view, this still seems reasonable, as the integration of elements from other subjects, be they physical experiments, German literature or the application of information technology, e.g. in maths instruction, always requires additional, if only minor, knowledge that exceeds the knowledge in one's major subject (in this case: mathematics). The model is a reminder of this – in the interest of competent instruction. (see specific discussion in Beckmann 2003a, b, c, d).

Level 2

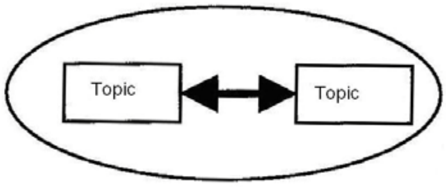
Parallel Topic-related Form (PT-Form)



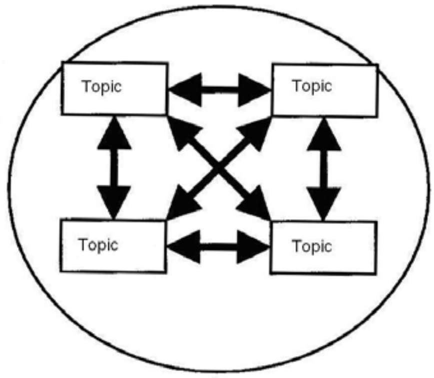
Here, several colleagues participate in the group work from the very beginning. The starting points are content that is common to various subjects. The teachers co-ordinate their teaching content for the whole year aiming at teaching the common content, if at all possible, at the same time. The emphasis of the co-operation during the school year is in particular on an intensive exchange of ideas and temporal agreements.

Topic-related parallel work corresponds basically to the Bergheim Model. The co-operation here is principally product-related, due to the fact that the results achieved in the parallel subjects are to be presented in a presentation session. In the student-moderator-model the co-operation is extended through student papers in respective parallel subjectx. (Landesinstitut fuer Schule und Weiterbildung, Soest 1999).

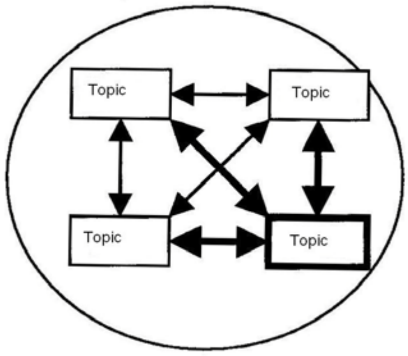
Basic Structure



Extension (variable):



In special cases, one teacher takes over the co-ordination, his/her subject becomes the major subject (as a consequence, the other subjects are less represented).



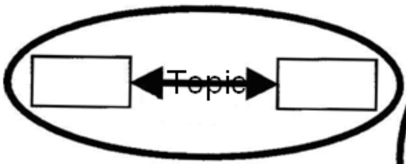
Subject-integrative Teaching

Level 3:
Parallel Planning Form (PP-Form)

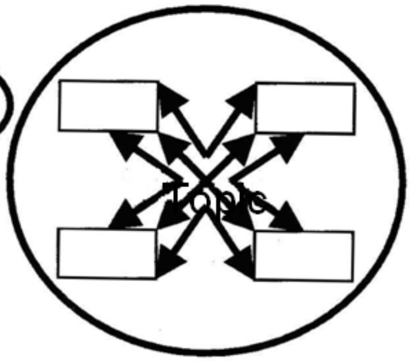
The collaboration of a team of teachers is motivated by a teaching topic that can/has to be dealt with jointly in many subjects. Here, the teachers plan the units jointly; they are in constant contact with each other exchanging ideas. It is also possible that one teacher takes over the co-ordination and her subject then becomes the major one. The intensive exchanges during the planning relate to the content, the methods and the objectives, the competencies to be acquired by the students but also the implementation of the organisation (see. IPTS no year, p.7).

In the planning, at least one adjournment or exchange of subjects must be taken into consideration, because it may become necessary in the course of the parallel work that certain subject areas have to be finished first, before the content of another subject can be worked on.

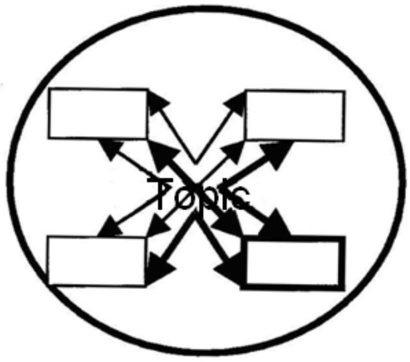
Basic structure/
With a major subject:



Extension (extendable):



Special form:



Level 4:
Joint Planning Form (JP – Form)

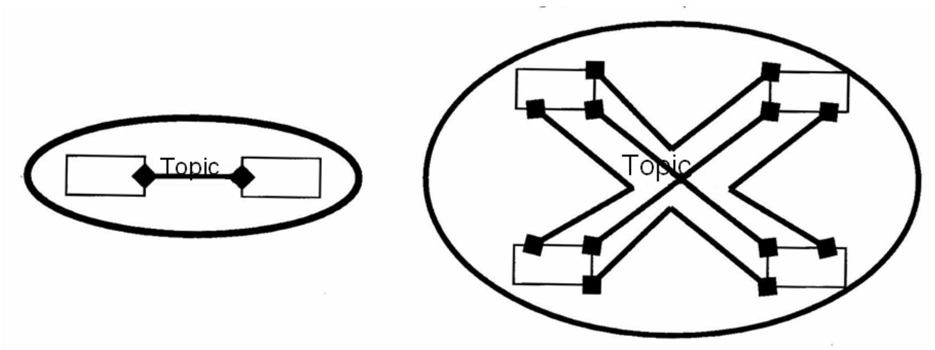
At the highest level of co-operation, the planning (as defined above) is done so closely that the complete instruction is done in group work. Planned group work is the most complex form of co-operation and an essential extension of the other forms of co-operation. The framework for the instruction is a topic or topic area that can only be mastered comprehensively in collaboration with several subjects. Typically, there are longer phases, in which some of the subjects involved do not play a clear role. On the other hand, however, all subjects are constantly and equally involved in the planning, so that, in principal, the special case of a co-ordination through a major subject is irrelevant.

Due to the present spectrum of subjects, joint planning sessions exist primarily in the form of inter-subject project work, in which the participating subjects only amalgamate for the duration of a project. It is only rarely customary[4] to orientate oneself by a course of study or a topic area

[4] One exception is f. e. found in the natural sciences in the form co-operation between chemistry and biology or possibly physics and geography, subjects in which the various and often independent topic areas can be worked on in courses of instruction. Often, however, individual projects are also more recommendable here (Cf. Beckmann 2003b)

over a whole school year, which would necessitate an extensive restructuring of the content as well as reflections of an organizational nature (see. Gallin, Ruf 1999 for the combination German(language)/Mathematics). As a final consequence, this form of co-operation might lead to the dissolution of the existing spectrum of subjects and could be viewed as an ideal scenario.

Basic Structure Extension (extendable):



Subject-integrative teaching obviously goes together with a (temporary) change in the subject structure. Huber calls this "discontinuing a subject" if instruction in the subject is discontinued for the time of the co-operation, and "subject supplementary", if a new integrative subject has been created (Huber 1997). Common examples of the former are project weeks, and for the latter "supplementary instruction", practiced at Oberstufen-Kolleg, Bielefeld or the "core courses" at the Hutchins School at Sonama State University (Huber 1997, p.61).

2.2.2 Co-operative Approaches

The form of co-operation does not specifically express anything about the time or the duration of the co-operation. These depend, essentially, on the question of the approach chosen in the co-operation, whether it is example-oriented, course-oriented or project-oriented. Details of each approach follow:

Example-oriented Approach

Didactic literature offers a number of suggestions for cross-curricular teaching (e.g., see list of examples in Beckmann 2003a). These are partly individual ideas which can be thematically classed with a group of topics or a targeted competence, which are, however, dealt with in isolation and which are occasionally presented without the overall framework.

The cross-curricular idea does not refer specifically to a long-term course, and the time of its application in school is not fixed either. Thus, such content can be integrated independently or concurrently in the school year syllabus. They may relate to one or several subjects, or they can integrate the students' manifold every day experiences that cannot be tied to a single school subject. We call this approach, which refers to the teaching of a cross-curricular example, example-oriented. Occasionally, suggestions for applications correspond to this approach.

This co-operative approach specifically concerns topic- and major subject-related work as well as topic-related parallel work.

Course-oriented Approach

It is also conceivable to relate the cross-curricular examples to a subject-oriented topic area, respectively, i.e., to plan an entire course. The term course is here to be understood as a "comprehensive methodological form" that serves the purpose of a "step by step instruction of a clearly defined form of knowledge or competence" (Meyer 1994, p.143). The proposition is then worked out on the background of the overall topic to be dealt with, and it is therefore more comprehensive and long-term than is the case with the example-oriented approach. We call this approach course-oriented. From a didactical point of view, it is quite imaginable on the background of this, to discard any suggestions, gained from the example-oriented co-operation, for the overall topic. On the other hand, cross-curricular aspects may result in a restructuring of subject-specific courses.

This co-operative approach is mostly relevant for the topic-related and the structural parallel work, but it is also conceivable in joint work.

Project-oriented Approach

Beside using the cross-curricular/subject-integrative approach in teaching an example or a whole course, it is also possible to make a project topic the starting point of a co-operation. The co-operation includes the typical characteristics of project work, such as (see. IPTS no date, p.8, Ludwig 1998):

- Initiative and discussion: a project idea is presented and discussed. Pupils and teachers participate
- Planning: Development of a project plan with all participants

- Execution: Independent work in small groups with regular plenary sessions
- Tests and Conclusion:
  - presentation of individual work/products and summing-up of overall result
  - presentation of project
  - evaluation of project

Since a project topic is (if possible) situational and takes its bearings from the participants, respectively, the social/practical relevance (Gudjons 1997), it is more comprehensive than an example and, as a rule, does not relate in all aspects to a specialized course. It is generally not restricted to one aspect of a particular subject but relates to cross-curricular contents. However, project work may also be subject-specific and may come from a topic taken from the major course involved.

Project oriented co-operation is thus not only limited to subject-integrative project work (project orientation with regard to planning joint work) but is conceivable on all levels of co-operation. This co-operative approach is therefore relevant for levels 1 to 4.

2.3 Contacts

Each subject is characterized by certain content, methods and objectives, a special language, tool kit and way of thinking. In cross-curricular and subject-integrative teaching these can differences clash. For instance an interpretive work from literature is quite different from the argumentation of a proof. To mark these differences, the term "Fremdheit" (alien-ness), coined by Mudroch (Mudroch 1993, p.149) in connection with interdisciplinary didactics, seems very appropriate to use.

2.3.1 Alien-ness of subjects

Alien-ness of content

Subjects differ in their contents. A look at the curricula confirms this.

It is questionable, however, if this alien-ness of content plays any role at all in the context of cross-curricular teaching. The co-operation is, after all, based on a common topic, which can even be a topic common to one or several subjects (particularly at level 1 and 2). Here, this alien-ness does not, indeed, refer to the common overall topic but refers to the different aspects of the content of each subject. In mathematics teaching, for example, under the topic of the circle, a particular number of points with geometric context and coinage can be dealt with, while in physics teaching the movement of a mass point is central.

At the co-operative levels 3 and 4, the common overall topic first dissolves the alien-ness of the content; however, in principle it is there, because the overall topic cannot, as a rule, be integrated into the syllabus of a subject, and each subject also has a different approach to its content. In addition, the unusual connection between a subject's contents is alien, too.

Linguistic Alien-ness

Subjects differ through the language that is used in them. Linguistic alien-ness can result from the fact that each subject has its own terms and terminology. This even applies to subjects with similarities, for example in the natural sciences. Alien-ness may also relate to the way things are expressed, i.e. whether a particular vocabulary is used, whether redundancy is possible, or whether formal language is used.

Alien-ness in the objectives

The objectives of a subject are essentially formulated by its didactics. They do not only influence its general targets but also the objectives of the individual content of lessons. Didactics is an inter-disciplinary science that has as its objective the learning and teaching of a subject in theory and practice. In its decisions, it does not only take into account subject matters but also, and in particular, pedagogical, psychological, social and sociological aspects, as well as educational-political, curricular, logistical and practical teaching considerations. Its objective is to reconcile socio-political targets, anthropogenic and sociological presuppositions with the conditions imposed by leisure time, and the constraints of the world of work and the environment.

Since most of the aspects mentioned are not subject related, the question arises whether there is actually any alien-ness in the objectives of the subjects. The fields to be considered lead to the conclusion that there is a congruence or consilience of the general objectives. It is the special achievement of didactics to select the relevant subject areas and connect them to educational objectives in such a way that they can contribute to their realization. This may, on the other hand, result in differences between the objectives of the individual subjects, or it may lead to a difference in the emphases, put on certain objectives. It may, for example, be a social objective to familiarize students with the methods of the natural sciences. Physics, chemistry or biology are more likely to adopt such objectives than the arts. In spite of a general agreement amongst subjects, as regards their objectives, there is alien-ness in details.

Alien-ness in Ways of Thinking

When students in a school project, conducted by Schneiter and Zimmermann, found out that their definitions, formulated in maths, were shown to the German teacher, they were enraged: "They felt deceived; said that it was a mean deceit, that they had paid no attention to the linguistic form and that they felt exposed now[5]" (Schneiter, Zimmermann 1985, p.48). This story highlights, beside the above mentioned linguistic differences, the alien-ness in the way of thinking, that shows in different subjects. While in ones native tongue, literature teaching, is an open way of thinking, including verbal imperfections, is acceptable, mathematical thinking is target-oriented and is, even during the search for a solution, presented in such a way as if it is only addressed to a mathematically informed audience (see Gallin, Ruf 1993, Wagenstein 1982). Thus one suspects that these traditional ways of thinking, in spite of recent publications on maths didactics, have not been replaced everywhere.

The alien-ness in the various subjects' ways of thinking is especially obvious in physics instruction. One of the objectives there is to familiarize students with the methodology of physics and its way of thinking. What is special about this approach is the concept of nature in physics. Physics means "the reduction of man to a physicist" and "the reduction of nature to an object of physics" (Oy 1997, p.29). What is meant here is, that "man as a physicist can do without certain senses and perceptions. He does not, for example, need a sense of temperature and the ability to distinguish between colours." Additionally, it means "that certain natural phenomena cannot be registered by the physicist" or, that among the natural qualities registered, "their special traits such as the red of the colour red or the quality of a sound, are not of importance to the physicist."[6] (Oy 1997, p.29)

Methodological Alien-ness

Different subjects differ in their methods. These differences were already pointed out above with regard to language of methodology. In general, the methodology used by different subjects, is described by their respective didactics. They are closely connected to their objectives, and as far

[5] Editorial note: The author is alluding to the fact that students often do not pay explicit attention to the rules of grammar, syntax and semantics when writing mathematics, given their prevalent notion that mathematics is more about the notation and formalism, as opposed to description and exposition.

[6] sic

as they relate to general objectives and the didactic principles attached to them, they are quite similar.

However, methodological alien-ness is one of the most conspicuous characteristics when we compare school subjects. This may relate to the individual methods learned and applied, such as writing a satire in a German language class, doing sketches in an art class, applying the Pythagoras theorem in mathematics, writing the notes of a short tune in music, planning an experiment in chemistry and dribbling in sports; however, it may also refer to the entire course structure, such as the inductive/deductive[7] method in physics.

2.3.2 Commonalities of Subjects

Since different subjects are characterized by alien-ness, the question is, aren't there any similarities? Possible similarities have already been mentioned in the analysis above. They relate in particular to the overall objectives and also to individual topics. There are certain parallels among "related" subjects in the language and the methodology used, for example grammar in languages and the inductive/deductive method in the natural sciences. Common features may be reasons for cross-curricular teaching. Co-operation is, however, only interesting here, as long as each subject has its own characteristics as regards content, concept and methodology. Cross-curricular/subject integrative teaching lives off alien-ness.

The alien-ness of subjects does not make a statement about its instructional implementation. This leads us to an extension of our co-operation model in that the contacts with "alien" aspects (alien content, methods, ways of thinking, objectives, language) are taken into account and different forms are distinguished.

2.3.3 Types of Contact

In co-operating, the teachers learn the alien aspects of other subjects through feedback (TM – Form), through agreements (PT-Form), through intensive exchanges (PP-Form) or joint work (JP-Form). The instructional implementation, however, requires that the teachers involved actu-

[7] Editorial Note: Inductive/deductive in the sense of Francis Bacon (1561-1626)a controversial figure in the history of the sciences. Bacon's rejection of the Aristotelian tradition, and formulation of the inductive method for science should rightly place him as one of the fathers of modern science. Newton's *Principia* and *Opticks* reflect the use of inductive arguments as a methodological principle carefully spelled out by Bacon in the *Novum Organum* nearly sixty years earlier.

ally realize the alien aspects and are capable of demarcating them from aspects of their own subjects.

This requires a fixed terminology:

On the Term Idiosyncratic Aspects (IA)

Starting from a certain subject, the term idiosyncratic aspect denotes the subject areas (content, methods, objectives etc.) which are validated by the subject's didactic principles. These may be general aspects, such as the deductive method, but also singular aspects like doing classical geometrical constructions with straightedge and compass.

On the Term Alien Aspects (AA)

Starting again from a particular subject, the term alien aspect refers to the idiosyncratic aspects of a different subject (co-operating subject), which differ from the aspects of the original subject.

The differences may be total, e.g. German literature as subject material, or may only concern parts of a common aspect. Alien aspects can thus be recognized by comparing common aspects. In a co-operation, the idiosyncratic aspects of the individual subjects become alien aspects as far as they distinguish themselves from those of the co-operating subject.

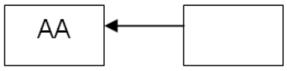
The contact with alien aspects can be closer or less so and is expressed in three ways:

Use of Alien Aspects

The teacher can use the alien aspects to enrich the topic through the use of alien contents or objectives, or master the topic by using different methods, a different language or a different way of thinking.

One example of this is given in the support given to mastering a mathematical topic by using the methods and contents of a German language class, such as individual text production (Maier 2000, Selter 1994), or the use of German literature (Beckmann 1994, 1995, 1999). Another example is the use of experiments (physics methodology) in maths teaching (Beckmann 1999a).

The use of alien aspects is most evident if the teacher was made familiar with these through feedback, respectively supportive work.



Integration of Alien Aspects

The teacher can connect alien aspects with subject specific aspects, respectively teach them in connection with aspects of his/her own subject. This can be done by relating them to the instruction running in parallel or directly. Directly here means, that not only the subject aspect is broached or applied in class or in a joint project but also the alien aspect.

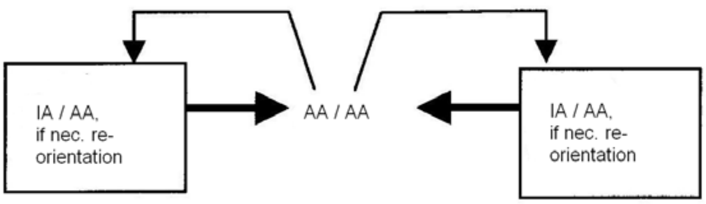
Examples of this are broaching the subject of common forms of presentation in chemistry and maths (Köhler 1992), the aesthetic reception or interpretation of a literary work containing a maths problem (Beckmann 2003c), the description of a tune through vectors in music (Wilke 1976), or the repeated application of algorithms to mathematical objects for the creation of works of art such as the Sierpinski Gasket (Peitgen, Jürgens, Saupe 1992).

Possibilities for integration ensue in particular, whenever alien aspects clash during the exchange of ideas, when the teaching procedure was agreed upon beforehand and the integration reflected upon jointly.

The more intensive the exchange of ideas, the more intensively the integration can be realized. The results in differences with respective alien aspect to become blurred.

Mixing Aspects

In planning a subject integrative teaching sequence or a joint project, a particularly intensive discussion about the alien aspects takes place. The alien aspects do not just clash, but they have to be put in relation to each other, which can go beyond simple integration, or is at least a form of particularly comprehensive integration. Their connection must make it possible to carry out a joint teaching sequence or a joint project. As a last consequence, this could lead to partially relinquishing the system of one's own subject and to a re-orientation.



2.4 Interest

Cross-curricular/subject-integrative teaching can potentially be meaningless, unless the contact goes together with an enrichment (in a positive sense) of the subjects involved (Mudroch 1993). Thus, the interest in cross-curricular/subject-integrative teaching must always be directed at enrichment (to avoid any misunderstanding: We are not talking about the personal interests of teachers, but the pedagogical-didactical interest directed at the students for the sake of successful instruction), in order to preserve the intellectual integrity of the subjects being taught.

An enrichment of the subjects can be achieved by considering their alien-ness, or (potentially) their common features.

It is therefore imaginable that the scientific method, common throughout the natural sciences, can be used more comprehensively in more subjects. What is more, in the alien-ness of the subjects there seems to be a special opportunity for cross-curricular teaching. On the one hand, it makes it possible to deal with a multitude of topics, unrelated to the subject itself, and on the other hand, it opens up new approaches to subject-specific contents. This way, different types of interest can be distinguished.

2.4.1 Orientation towards Interests

Co-operation may be motivated by a singular interest but may also involve several interests at the same time; it may orient itself to <u>alien-ness</u> or (potentially) to <u>common ground</u>.

- Orientation towards content: The inter-subject approach facilitates the work on a particular content.
  For example, certain biological questions, such as research into the biological population of a pond, can only be answered with the help of mathematics (Cf. Shahani, Parsons, Meacock 1979).

- Orientation towards Methods: The inter-subject approach facilitates the working out of a particular method (including linguistic method).

For example, the teaching of mathematical transformations in the context of musical transformations (retrogression) can be supplemented by the musical effects achieved through it (Dienes 1987, Nisbet 1991).

- Orientation towards Competence: The inter-subject approach promotes certain competences. In cognitive psychology, competences are individual prerequisites for behaviour and types of experiences (Flammer 1999, p.19).
  For example, carrying out and evaluating a physics experiment can activate functional thinking through the need for switching between different forms of presentation (tables, graphs, functional equations etc.).

- Orientation towards Ways of Thinking: The inter-subject approach improves the access to certain ways of thinking.

2.4.2 Forms of Interest Orientation

Interest orientations may take various forms.

Subject Orientation

The starting point here are two (or more) subjects (S1, S2 …) aiming at a co-operation.
S1 is used here to introduce, discover, work out, explain, describe connections with S2 in order to create or structure objects in S2. On the surface, it is all about teaching something about S2. That way, using S1 is an enrichment of S2. On the other hand, S1 also profits from this. By using S1 to teach S2, its importance for topics outside that subject becomes obvious.

This form particularly based on the alien-ness of the subjects. As the relation to the subject is dominant, it mainly concerns cross-curricular teaching and subject-integrative teaching less so.

Parallel Orientation

The characteristic of this form is the parallelism of different subjects S1, S2 … . We can distinguish two types, depending on how closely the common features are treated:

I) The subjects are worked on in parallel in that

- a common aspect (topic, method etc.) is worked on jointly

- common aspects of the subjects are worked on simultaneously, on the basis of a subject-related topic (e.g. from S1).

An example for this is working on the parable in German and maths (Beckmann 2000) or the circle in physics and maths (Beckmann 2003b).

II) The class reflects, consciously and simultaneously, on the common features of both subjects by making the common aspects their topic in both the subjects involved.

One example of this is consciously making these formal aspects the topics of chemistry and maths instruction, however, with different intentions (Köhler 1992).

Indicators of this form are the (seemingly) common features of different subjects. The common topics or the common aspects (methods, ways of thinking) open up the opportunity to work on these related aspects in a more varied but also more critical way.

Comprehensive Orientation

The subjects can also be enriched in the way that each subject makes a contribution to the work on a topic that is not tied to a particular subject. The subject integrative topic forms the starting point of a co-operation. It has to enable all subjects involved to make an informed contribution.

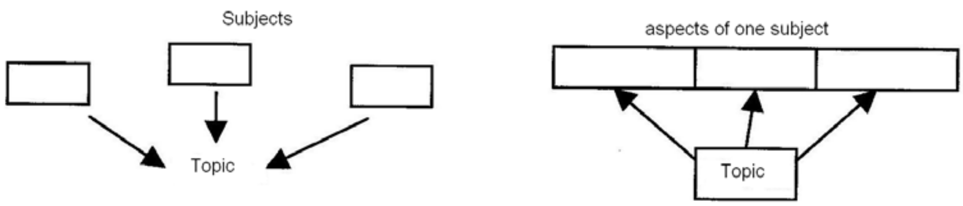
The characteristics of this approach is

- the use of subject-related aspects in non-subject contexts
- the experience of the importance of subject-related aspects for non-subject contexts
- the combination of subject and alien aspects.

In comprehensive orientation, alien-ness plays an important role, in that each subject has its own special access to the topic. On the one hand, it contains a special potential for comprehensive work, on the other hand, however, there is a problem. In comprehensive orientation the forms of alien-ness crash more directly than in subject orientation, where the alien aspect is used consciously for enrichment, or in parallel orientation, where the discovery of alien-ness is the actual support of the co-operation. In a comprehensive orientation approach to teaching, alien aspects might converge in such a way, that they exclude each other in the worst possible case. Co-operation in comprehensive orientation might therefore require a change in the systemic of a subject.

Such co-operation requires the teachers to have sound knowledge of all aspects of their subjects. First of all, the subject teacher must be able to recognize that a topic is relevant for his subject (roughly corresponding to the magnet mode in projects, Ludwig 1998). Secondly, s/he must be able to correlate the subject's aspects to the topic (roughly corresponding to the star mode, here, however, applied to any subject and related to those aspects, Ludwig 1998, cf. graph).

Due to the fact that the starting point is a non-subject topic, this characteristic mostly concerns subject-integrative forms of co-operation.



Explanation: Comprehensive orientation requires a topic that concerns (attracts) one's own subject, and that one has a complete survey of which subject-related aspects the topic contacts.

2.5 Systemics

Scientific research takes place within a systematic canon or system of thought, determined by the respective discipline. With regard to school subjects, the didactics of a subject determines the systematic framework for instruction. It determines the questions, methods and objectives. Each subject is thus given its own set of systemics.

Cross- curricular teaching is characterized by co-operation, in which contact is made with alien aspects. Mastering a topic requires coming to terms with the alien aspects of the other subjects. The question is, what kind of consequences does the co-operation of different subjects have for the subject-specific systemics, e. g., does cross-curricular teaching have to lead to (temporarily) giving up the systemics of the individual subject, respectively does cross-curricular teaching follow its own systemic?

The question whether, or in how far, the systemics of the subject deviates from the systemics prescribed by its didactics, obviously depends on the level of co-operation, its starting point, the form of contact and the interest orientation. In the following table, the possibilities of cross-curricular/subject-integrative teaching are collected. It has to be observed that for certain forms of co-operation, due to their structure as described, certain forms of contact must be excluded. In the same way, example-oriented co-operation does not take place at all levels. Theoretically, it is thinkable to practice subject-integrative co-operation (level 3 and 4) in an example-oriented way. However, as the co-operation is very tight here and is based on planned work, the practical example will rather turn into a (small) project.

<table>
<tr><th>Level</th><th></th><th>Form of Co-operation</th><th>Co-operative approach</th><th>Form of Contact</th><th>Interest Orientation</th><th>Characteristic</th></tr>
<tr><td>1</td><td>Cross-curricular</td><td>TM – Form
Topic and Major subject -related-Form</td><td>example-, course-, project-oriented</td><td>use of Alien Aspects
(if nec. integration)</td><td rowspan="4">alien-, communal-oriented (by Alien Aspects, by Idiosyncratic Aspects)

content-, method-, competence-, thought-Oriented</td><td>subject-parallel-Oriented</td></tr>
<tr><td>2</td><td>Cross-curricular</td><td>PT – Form
Parallel Topic – related - Form</td><td>example-, course-, project-oriented</td><td>use and integration of Alien Aspects</td><td>subject-, parallel- orientation (resp. comprehensive orientation)</td></tr>
<tr><td>3</td><td>Subject-integrative</td><td>PP – Form
Parallel Planning – Form</td><td>course-, project-oriented</td><td>use, integration, mixing of Alien Aspects</td><td>subject-, parallel-, comprehensive orientation</td></tr>
<tr><td>4</td><td>Subject-integrative</td><td>JP – Form
Joint Planning Form</td><td>course-, project-oriented</td><td>integration of Alien Aspects, mixing Aspects</td><td>comprehensive (also parallel orientation)</td></tr>
</table>

Table 1
Possibilities of cross-curricular/subject-integrative teaching

The table above indicates that a rise in the levels is connected to a decrease in subject systemics towards an original subject-integrative/cross-curricular systemics. As long as the topic- and subject-related work only makes use of the alien aspects, the major subject can essentially retain its autonomy and thereby its own subject didactics. Co-operation at the higher levels, however, in particular the integration of alien aspects, mixing them with alien aspects, but also project orientation, may mean a tighter connection, which makes keeping the systemics of a subject at least somewhat more difficult.

2.6 A Second Definition of Terms

The theoretical considerations lead us to an extension of the first definition:

Cross-curricular/subject-integrative instruction means dealing with a (subject-related or non-related) topic, in which the subject borders are exceeded and other subjects are integrated.

The instruction is done in *co-operation*.
The co-operation can consist of topic- and major subject-related work (TM-Form, level 1), of parallel topic related work (PT-Form, level 2), of parallel planning work (PP-Form, level 3) and of the planning of joint work (JP-Form, level 4). It may be example oriented, course oriented or project oriented.
Instruction on levels 1 and 2 is termed *cross-curricular*, on levels 3 and 4 it is termed *subject- integrative*.

Exceeding subject borders results in *contact* with other subjects. Here, common interest *(Idiosyncratic Aspects)* but also alien interests (*Alien-ness)* meet. They may be related by making use of the alien aspects, by integrating the alien aspects or by mixing subject and alien aspects.

The interest in cross-curricular/subject-integrative teaching lies in an *enrichment* of the subjects. Here, the interest can orient itself to common aspects or to alien aspects. It may be oriented to content, methods, competences and ways of thinking, and it may appear in the form of subject orientation, parallel orientation and comprehensive orientation.

2.7 Specializing: Applying the Model to a particular Subject

The model for cross-curricular teaching describes the theory of any cross-curricular instruction, i.e. the theory of cross-curricular maths, German, physical education etc.

Cross-curricular/subject-integrative maths instruction (German, physical education etc.) is a form of instruction, in which one of the subjects involved is maths (German, physical education etc.).

In relation to a particular subject X, there are certain specializations (X stands for a particular subject and is replaced by M for maths, D for German, S for phys. ed. etc.):

In topic- and major subject-related work, subject X is the major subject.

In the special forms of topic related work and parallel planning, subject X can be the major subject. In this case, the co-operation orientates itself to the interests of subject X. The alien aspects are on principle taken from other subjects. These are used, integrated or mixed to deepen the content, the methods etc. of X. Two kinds of subject orientations derive from this.

X-orientation (M-orientation, G-orientation, S-orientation etc.)

The starting point here is subject X. In the co-operation with subject S the content, methods etc. of X are applied (and possibly worked out) to introduce correlations in S, to discover, work out, explain, describe, create objects in S or to structure S.

We call this form of subject orientation X-oriented, since subject X plays a decisive role here. On the surface, the objective is to teach content from S. However, this content is developed and derived with the help of X. The basic approach is to teach the meaning of X (e. g. maths) by showing that X is necessary for the development of a certain content outside X. From the point of view of X this means, that the topic to be dealt with, is embedded in a content, taken from F, which is developed with the help of these connections from X.

S-orientation

The starting point here is the related subject S. Subject S is used to introduce connections in X, to discover, work out, explain, describe them, create objects in X or to structure X.

We call this form S-oriented, since the subject S is of particular importance here. On the surface, it is about the teaching of contents, methods, taken from X; these are, however, only absorbed, deepened or taught in an enriched way through the contents of F.

3 The Rationale for Cross-curricular / Subject-integrative Teaching[8]

3.1 Basics

3.1.1 Origin of Cross-curricular Teaching

The roots of cross-curricular teaching can be found in educational progressivism, which developed at the turn of the 19th/20th century (up to about 1933). Many of the objectives of cross-curricular teaching correspond to the principles of educational progressivism (see section 3.2). Educational progressivism resulted from the need to reorganize school for more humane learning. The "humane school"[9] was to be based on the freedom of the child (Montessori), his/her

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[8] For the sake of clarity, we will only speak of cross-curricular teaching in this chapter but subject-integrative teaching is meant here as well.

[9] Editorial note: The historic evolution of didactic traditions in Germany, France and Italy reveals several commonalties which can serve as a fertile source of discussion and for mediating common agendaz. In all three countries mathematics didactics has its origins in the humanistic movement that emerged in post Renaissance Europe. Humanism is typically viewed as a literary and cultural movement which began its spread through Western Europe in the 14th and 15th centuries. However histories of the Renaissanceindicate that humanism was also an educational curriculum with its roots in 14th century Italy with Guarino Veronese (1374-1406) in Ferrara and Vittorino da Feltre (1373-1446) at Mantua who began using Quintilian texts as a model for their educational program. The Italian poet and lawyer, Francesco Petrarca, or *Petrarch* (1304-74), is called the "father of humanism". The widespread transmission of classical texts with the serendipitous advent of the printing press led the humanistic movement into Germany, France and England where it mutated differently. In France, as we previously described, one of the mutations of humanism was the encyclopaedic tradition, which is characterized by

needs (Freinet) and on the laws of human development (Steiner) with due consideration of society's needs. The humane school therefore had to be a "new" school, a school that became the lifestyle of the students (Schoning 1999, p.22). The special characteristics of this school are the observation of knowledge derived from developmental psychology, the reference to real life (Freinet), free working time (Petersen, Montessori), the combination of practical and intellectual work (Kerschensteiner), holistic learning (Leipziger Lehrerverein etc.). In connection with cross-curricular teaching, Bertold Otto (1859 – 1933), who created a form of collective class, has to be mentioned in particular: at least three times a week instruction was to take place jointly, independent of the canon of subjects and the individual syllabuses, and it was to orient itself to the wishes of the students (Gudjon 1999). According to the model of cross-curricular teaching, this corresponds roughly to subject- integrative teaching on level 4.

Even if the idea of cross-curricular teaching was made concrete 100 years ago, this does not mean that it was generally accepted. School is, and has always been, conditioned by social/societal factors. A look at educational history points up the constant

> *"struggle to liberalize and democratize educational opportunities in the public school system", which is a multi-faceted, controversial process, which has been influenced by the political and economic needs to modernize, which again and again came up against barriers … which - once set in motion – can never be stopped completely". (Herrlitz, Hopf, Titze 1998, p.9).*

Curricular decisions have to be seen on this background. Thus, Bertolt Otto can also not be called the inventor of cross-curricular teaching but someone, who cumulated ideas developed before him. The general basic ideas can be found in Rousseau (1712-1778), who pleaded for the child's original contact with nature, in the philanthropists (a pedagogical movement from around 1750 to 1800), who postulated an "alternative to Latin scholarship" and an "utilitarian education with the objective to prepare children for usefulness in an economic and social environment" (Gujons 1999, p.89) and surely in Pestalozzi (1746 – 1827), who saw demonstrability and experience as the basis for learning.

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the principles of universality, rationality and utility In Germany, humanism in its new forms, mutated into a child-centered epistemology (or an emphasis on the individual), which have influenced the educational traditions of Anglo-Saxon countries (Sriraman & Törner, 2008).
Reference
Sriraman, B & Törner, G. (2008) Political Union/ Mathematical Education Disunion: Building Bridges in European Didactic Traditions. In L. English (Ed) **The Handbook of International Research in Mathematics Education (2nd Edition)**. Routledge, Taylor & Francis, New York. pp. 660-694.

Cross-curricular ideas can also be found in Humboldt's idea of a general education with the three elements (Gudjons 1999, p.94):

- individuality (one's own subjectivity)
- totality (forming all powers to wholeness instead of filling up students with material)
- universality (practical and intellectual education)

In cross-curricular teaching, works by Herbart (1776 – 1841) have to be considered. Herbart developed a basic concept of cognitive psychology with the elements of absorbing, thinking, assimilating and applying. This classification describes the concentration and the structure of a "circle of ideas" and supplies the formal basis for lesson planning, which Herbart was later criticized for by the reform pedagogues. His disciples tried to develop this into a system of culture levels. It is interesting to note that this already contained typical cross-curricular ideas:

> "With their idea of concentrating teaching they wanted to avoid overcharging the curriculum through too many subjects, an attempt that led to some absurd concentrations: …from the sea that Columbus crossed to the characteristics of water (physics and chemistry) and from their to Schiller's poem The Diver (German literature)." (Blankertz in Gudjons 1999, p.101; ann: The idea, Blankertz calls "absurd", might well be a project idea in modern subject integrative teaching).

The interest in educational progressivism today and its clear influence is not at all surprising. Today's basic pedagogical questions are similar to those 100 years ago, even if the historical background is different.

> "The historical parallel is amazing, though: Praxis gives new impulses, theory attempts to clarify and systematize it afterwards." (Gudjons 1999, p.102).

3.1.2 Epistemological Bases – The Unity of the Sciences

From an epistemological point of view, "the idea of the unity of science" serves as the background to cross-curricular teaching. It means the following: (Mittelsträß in Gräfrath, Huber, Uhlemann 1991, p.1):

The unity of science exists or a well founded programme of its representation,

1. because the world as the object of science is one (unity of nature)

2. because the scientific interest is one (it is the rational understanding of the world)

3. because the criteria of rationality, and by implication the methods also, that guide scientific work, tentatively refer to unity (criteria for rationality are expressions of the same idea of scientific rationality)

4. because, philosophically, the idea of reason is one and is the highest criterion for rational action

5. because the researching subject is one and science is not without a subject.

The idea of the unity of science is not at all new. In antiquity, this unity resulted by itself as the ontological unity of nature. In modern times, this view changed in that there is no objective unity of science but that science is seen as an idea of human reason (Gräfrath, Huber, Uhlemann 1991). Two typical concepts of unity, which are based on the unity of human reason but which are still as concepts essentially different, are those of Leibniz and Kant. Kant's normative-transcendental approach is based on the idea that knowledge is not given *a priori* by primary cognition and action but that people have to discuss their experiences and through this establish meaning. Leibniz' holistic approach on the other hand, is based on the logical structure of the world, made up of inseparable units and a fixed method of their combinations.

Another modern philosophy that, in the 20th century, pursued the idea of the unity of science is the logical empiricism of the Viennese circle. Their main aim was to bring together the knowledge, gained in the individual sciences, in a unified science. Their basic theorem is: *All scientific knowledge is grounded in experience.* The idea that statements about experiences need to be empirically controlled, results in the theorem on meaning: *A statement is meaningful if it can be verified.*

As a consequence of this guiding principle, the idea of cross-curricular instruction plays an important role in logical empiricism. The motive behind the search for the unity of science was the idea that work on complex questions, necessitating the transgression of individual subjects, requires unifying respectively relating the terms and theorems of the diverse disciplines. On the other hand, the verification of a theorem requires the unification of the language used by the theorist who puts forward the hypothesis, as well as that of the observer who examines the hypothesis. However, in the implementation of these ideas logical empiricism reached its limits, resulting in a series of suggestions for improvement, such as the falsification method by Popper, i.e. the verification of negations as a criterion. All in all, one can state that the question of the unified concept of logical empiricism could not be solved satisfactorily. It is remarkable on the other hand, that certain applications of the concept even led to devisive scientific theories (e.g. Comte's division of the experimental disciplines).

A trend that has established itself since about 1940 and that pursued the idea of the unity of science, has become known by the name *system theory*. Important representatives are Bertalanffy, Rapaport, Boulding as well as Wiener. From a theoretical point of view, the system theory approaches correspond to the holistic approach. The characteristic feature here, however, is the importance of the self-reference, self-regulation of elements, respectively the mutual effects of the different elements of a unit. In this context, it is worth mentioning Piaget, who drew special conclusions from system theory for the trans- and inter-disciplinary qualities of subjects (subject combinations at science level) (Vonèche 1993): Piaget's basic term is *structure* as a system of existing transformations whose results are again part of the system. It is Piaget's idea that this mechanism characterizes every scientific discipline. Depending on the kind of relationship the special sciences have with each other, there will be progress. In *multi- or pluri-disciplinary* situations an exchange of information takes place that does not, however, lead to self-regulation. The interdisciplinary character implies activities between the sciences. These are, according to Piaget, compulsory and the differences remain. Piaget therefore pleads for the over-arching discipline, *trans-disciplinariness*, where all elements (here, the special sciences with all their factors) interact. Only this way, self-regulation is possible. The interaction between maths and physics (Cf. e.g. Zeidler 1998) is a good example of the progress made possible through trans-disciplinariness.

> "Maths enlivens physics. However, once activated, maths receives repercussions from physics that change it… This dual movement towards a renewal is in itself a sign for the move in the sciences" (Vonèche 1994 in translation, p.115).

Transferring these thoughts to cross-curricular teaching would mean that there is only a gain in the mixture of alien aspects and renewal (Cf. model). However, Piaget's point of view is quite extreme here (Cf. complementariness). In addition to this, cross-curricular teaching does not only serve the purpose of progressing knowledge but pursues a series of other goals (Cf. 3.2).

More recent theories of science are more modest with regard to the idea of the unity of sciences. They are only discussing individual criteria as the measure of their characterization, such as a uniform scientific terminology, uniform scientific laws, methods or contents (Gräfrath, Huber, Uhlemann 1991).

A transfer of the idea of the unity of science to schools can be of importance for cross-curricular teaching, in that it, e.g. draws attention to the possibility of difficulties in understanding between different subjects. In addition it motivates people in their search for the unity of all school subjects. Indeed, looking at uniformity from a superior point of view one can observe that the general objectives of all subject didactics are similar, in that they take into account concepts of developmental psychology and social concerns in teaching suggestions. A certain uniformity of the subjects shows in their respective teaching concepts. Examples are independent study and interactive instruction.

However, the unity of all subjects does actually not correspond to the interests of cross-curricular teaching. According to the model of cross-curricular teaching, the teaching across subjects only becomes interesting through alien-ness. From a theoretical scientific point of view, this corresponds exactly to its meaning: The idea of the unity of science is not in opposition to multi-disciplinary teaching. It is simply rather "unity in variety". The necessary specializations in the different disciplines are accepted, however, the disciplines and their knowledge are not seen in isolation but within an interconnected system. For its description the term complementariness is well suited (Gräfrath, Huber, Uhlemann 1991, p.3).

> "Each discipline has its own access to the world, but points beyond itself, insofar as it cannot grasp the world (scientifically) by itself. Problems of science don't adapt to the borders drawn up by the historically grown disciplines. They often make it necessary that a scientific discipline and the individual scientist keep an eye open for cross-curricular questions. Transgressing ideas of unity find, on the one hand, a methodological expression in the application of rational criteria and on the other hand become obvious in their understanding of science as unified research, in which the drawing of borders by individual disciplines is second rate."

3.2 Objective of Cross-curricular Teaching

The objective of cross-curricular teaching has already been integrated into its model. It can be found there under the dimension of *interest* :

The objective of cross-curricular teaching must be enrichment. Here, the interest can orientate itself to the common features or to alien-ness. It can be orientated towards content, method, competence and way of thinking, as well as to the characteristic forms of subject-, parallel- and comprehensive-orientation.

The decision to teach in a cross-curricular way must therefore be preceded by an analysis of its objective, which ensures (to a large extent) that enrichment is part of it. In detail, this requires e.g. the consideration that acquiring a subject competence (with competence and subject-orientation) is made easier through alien aspects. This requires, however, a basis for such judgement, such as higher ranking criteria, that are applicable to the respective individual case. At the same time, the higher ranking criteria form a rationale for cross-curricular teaching and arise, apart from subject aspects, from different disciplines such as education, psychology and the theory of science.

We will now present the objectives of cross-curricular teaching and explain them briefly. It will be shown that the arguments speak in favour of the fact that these objectives can be reached in cross-curricular teaching (which, for the moment, excludes any statement about subject-specific teaching). On the background of a concrete implementation, they may, however, appear to be quite general, for, according to the cross-curricular model, there is not just one type of cross-curricular teaching but quite different ones. In addition, not every objective is prevalent in every grade:

- In the first grades in secondary I, (as well as in primary school) those objectives that enable students to have concrete and graphic experiences (in particular objectives 3.2.1 to 3.2.3, 3.2.7, 3.2.9 to 3.2.12) are predominant.
- In the middle grades of secondary I, complex questions and general principles, the reference to reality with its social, technological etc. developments become more and more important (objectives 3.2.1 to 3.2.3, 3.2.5, 3.2.7, 3.2.9 to 3.2.15).
- At the end of secondary I and in secondary II a new dimension is added, notably (conscious) reflection and making cross-curricular work the topic of the work in class (in particular objectives 3.2.4 to 3.2.8, 3.2.14, 3.2.15, but all others as well).

The decisive question, however, is whether the advantages connected with the objectives are actually real ones (expectably so). <u>Cross-curricular teaching requires a critical discussion of the objectives in each individual case – and in comparison with subject-specific teaching.</u>

In the following, possible objectives are listed.

3.2.1 Cross-curricular Teaching as a Special Opportunity for Student Orientation

Student orientation is a comprehensive term referring to the general approach in educational progressivism "student oriented learning". It is based on results from the psychology of learning and developmental psychology, as well as on a concern for the students' perspectives and interests. As a pedagogical principle, student orientation has grown out of theories that look at the student as a person and as a cognitive but also affective and social being.

A series of psychological theories is available for the observation of developmental-psychological aspects. From the teacher's or the pedagogue's point of view, it is of interest to know, which conditions have to be created to have a positive influence on learning and development. *Learning* means the achievement of small, short term and often temporary changes in competence, habits, values, physical strength etc. . The modern view of learning starts from the assumption that structures (concepts, rules etc.) are innate in man and in the child; that these have to be related to the experiences (stimuli) made in the world, checked and, if necessary, modified accordingly. Learning means changing these structures: learning is *structural* (Cf. Lefrancois 1994, Flammer 1999).

The central notions of modern cognitive psychology are attention and memory (inclusive of remembering). Learning means, paying attention. Only those stimuli, that get attention, are selected, processed, coded, i.e. formed terminologically. Attention is influenced by structures already in existence. Despite the fact that coded information is stored for life (long term memory), it cannot always be called up. The ability to call up information, respectively remember things, is not only important in itself, but also for the transfer of knowledge. Certain stimuli, either external or provided by the learner on account of existing information, are of crucial importance for our memory. Here, strategies for organizing material, thus the abstraction of meaning from material (Lefrancois 1994, p.175), are helpful besides repetition and structuring.

Development is characterized by long term changes (in most cases, of several areas simultaneously) and includes processes conditioned by maturity. Development is also structural, i.e. not only single elements change, such as abilities, opinions etc., but also the structure of these elements, the total structure. Flammer marks development as the *class of those changes* that incur further changes (Flammer 1999, p.19). There exists a mutual effect between learning and development: learning processes can trigger off developmental processes, development makes new learning processes possible. The developmental theories name various activators for developments, like crisis management as the resolution of tensions between negative and positive tendencies (psycho-social theory, Erikson), want satisfaction (psychoanalytical theories) with goals such as freedom, justice and the dignity of man (humanistic psychology), tendencies to create a balance (systemic directions) between the individual and the world, between different structural elements (schemes) and between scheme and structure (Piaget), targets and the solution of problems (Case), actions of the greatest possible variety and structural complexity (contextual theories), self-control of the individual (Thomae, Lerner, et al.), but also interaction with other people and role changes (Bronfenbrenner) (Cf. Flammer 1999).

The psychological theories supply arguments for cross-curricular teaching. In particular, the cross-curricular components alien-ness and co-operation seem to promote student orientation: Integrating alien aspects promises variety, and specific aspects gain in importance (Cf. applied maths instruction). The new contents and methods create new, possibly even more complex opportunities for action. Through variety one can expect that more attention will be given to the new information, in that students are given more opportunities to connect with existing structures, but also that individual processes can be stimulated more often. In addition, integrating other subjects makes role changes possible, respectively the interaction with people representing different roles etc. .

The theoretical discussion, touched upon here, can be understood in the way that cross-curricular teaching may be a practical approach to student orientation. However, it must not be overlooked that quite general terms clash here. The complexity of cross-curricular teaching becomes obvious in the model, and Meyer even notes (Meyer 1994, p.110) :

> “General targets such as openness, student orientation etc. sound demanding and interesting, however, their disadvantage is that they are only able to be grasped precisely after awkward work, requiring many additional decisions and still remaining controversial.”

Some of the following arguments for cross-curricular teaching also concern student orientation and make it more precise. They consider, in particular, also affective and social aspects.

3.2.2 Cross-curricular Teaching as a Field for Holistic Learning

Next to student orientation, holistic learning (which is inseparable from student orientation and makes it more precise) is an argument that is often put forward in favour of cross-curricular teaching (Tenorth 1997). Holistic learning can be characterized very graphically with Pestalozzi's famous triad "Learning with head, heart and hand" and considers emotional learning and learning by doing important components of human development.

Holistic learning is characteristic of humanistic education, which, among others, can be justified by humanistic psychology but also by the structural genetic tradition (Baldwin, Piaget). In humanistic psychology, learning is understood as a"deeply human, personal, affective experience", … as a "personal discovery of meaning", because we "have feelings or emotions if events are important to us" (Fatzer 1998, p.66, 67). Humanistic psychology puts emphasis on the self-concept as a factor in human development. The decisive condition for development is the acceptance of one's self, respectively the feeling of being accepted (Flammer 1999). Accordingly, the basis of humanistic psychology is the conception of man as an entity of spirit, body and soul. Education is to promote this entity (Fatzer 1998, p.18). Its pedagogical components are given as: respect and good will, non-prescriptiveness, truth and warmth (Rogers, cf. Flammer 1999), an emphasis on intrinsic learning (Maslow), the "development of the self" through consciousness of one's own motives, abstract thinking and conscious action (Weinstein, Fatzer 1998) as well as a consideration for the student's need for identity, belonging and self-determination ("Affective Education Program" according to Newberg).

In its implementation in school, this leads to an instruction that is oriented to experience and therefore cross-curricular (Cf. Fatzer 1998). Humanistic pedagogues in particular, like Goodlad, see a strong tendency to prescriptiveness in the canon of subjects, that contradicts the development of the self. In the following quotation from a paper, delivered at the fourth national conference on humanistic education 1977 in Georgia, Goodlad distinguishes between a hard and a soft (humanistic) education (Goodlad in Fatzer 1998, p. 49):

> "Der harte rigide Stil umfaßt klar definierte und voneinander abgetrennte Fächer oder Disziplinen….
> Für den weichen und zarten Stil …. Ein breites Angebot an Lernzielen mit einem Hauptgewicht auf Verstehen und Wahrnehmen des eigenen Selbst ist typisch. Eine

> Tendenz zur Integration verschiedener Fächer oder zum sog. ´integrativen Tag´ ist ein weiteres Merkmal dieses Ansatzes….“

Another approach to holistic teaching (through interactive-ness) originates from the structural genetic tradition. The central concepts, e.g. in Baldwin and Piaget, are *scheme and structure*, *assimilation and accommodation* as well as the *circular reactions*. *Assimilation* is the “adaptation by the subject of an environment to the possibilities for action, respectively to the epistemological conditions of the subject”; accommodation conversely means the “adaptation of the actional and epistemological possibilities to the demands of the situation” (Flammer 1999, p.117f). *Schemata* are the given or acquired epistemic possibilities that are assimilated to the environment, respectively that accommodate themselves. The (cognitive) *structures* are the organized connections of the schemata. The *circular reactions* describe the close connection and the dynamic exchange between assimilation and accommodation. According to Flammer, they are the essential core of developmental processes (Flammer 1999): after the scheme has been activated, circular reactions keep it active, they activate a (positive) scheme for another opportunity and vary it spontaneously. This theory gained special importance for schools through Aebli, whose two volume work has the significant title “Denken: das Ordnen des Tuns”(Aebli 1980, 1981) and who speaks for interactive teaching (Cf. Gudjons 1997) with his thesis “Thinking issues from action” (Aebli 1980, p.26).

On the basis of the theories dealt with, cross-curricular, respectively subject-integrative teaching seems to be able to comply well with the demand for a holistic approach, in that it shows signs of an orientation towards experience and action (Cf. Gudjons 1997, Beckmann 1999) as well as meaning, and therefore (possibly) offers more opportunities for assimilation and accommodation processes or circular reactions. Cross-curricular teaching in particular allows holistic teaching methods, such as “group work, partner work, project work, story telling, various forms of scenic representation, freeze frames, role play, simulation games, experiments, exploration” etc. (Jank, Meyer 1994, p.356, cf. also Fatzer 1998 and following paragraphs).

3.2.3 Cross-curricular Teaching as a Particular Opportunity for Motivation

Motivation is essential for the understanding of human learning. Motivation influences and guides a particular behaviour. To be more precise, motivation means “the active concentration of one's present conduct on a positively valued target. This alignment involves different processes with regard to behaviour and experience" (Rheinberg, 1997, p.14).

Different theories of motivation name different motivational variables, e.g. expectation and reward, and in particular excitement. A condition of optimal excitement is highly conducive to learning. According to Berlyne, newness, meaningfulness, complexity and the surprise effect of a stimulus affect increased excitement (Lefrancois 1994, p.192). Cross-curricular teaching then seems to be interesting from a motivational-psychological point of view (cf. also 3.2.1).

3.2.4 Cross-curricular Teaching as Field for a New Way of Thinking

For the last few years, there often has been a demand for a "new way of thinking"- e.g. in politics and the sciences – that is no longer linear but multiple and linked; a way of thinking that allows us to grasp the complexity of our environment and our day to day lives. Reality seems linked and gives feedbacks: Every change has multiple causes and effects (Flammer 1999).

The "multiply linked global problems of mankind do not only call for technical, scientific or sociological, philosophical knowledge, but more than ever for holistic thinking, that knows how to integrate the different subject perspectives" (Mainzer 1993, p. 41). Mainzer makes this idea more concrete by a cross-curricular question (Mainzer 1993. p.46):

> "How can the ecological problems of today's industrial society be solved with the modern instruments of the market economy and of technology, while observing an environmental ethic?"

There is a demand for a form of thinking that, with every action or with every phenomenon, takes into consideration all (or as many as possible) causes and consequences respectively linkages.

The demand for linked thinking speaks clearly in favour of cross-curricular teaching, since it is there that multiplicity and linking is achieved by integrating, respectively mixing alien contents, methods, ways of thinking etc. . It allows a view of the whole, of the "phenomenon"as such. Wagenschein characterizes it like this (Wagenschein 1998, p.135, 136):

> "Understanding implies: standing by the phenomena" …"and in such a way that we see them as counterparts and allow them to have an effect on us, yet without prejudice and without intervention, just impartially, not fixed to a particular aspect."

Wagenschein reminds us here of the lack of links between the school subjects, and that each subject only ever teaches a single aspect or part of the total reality. He also wants to remind us of the common educational task of all subjects.

It should not be overlooked, however, that the demand for linked thinking also speaks in favour of subject teaching, because the ability to grasp the links is in many cases only possible with thorough subject knowledge.

3.2.5 **Cross-curricular Teaching as an Opportunity to Reflect on Subject-specific Methods**

The demand for linked thinking goes together with the demand to organize learning processes in a non-linear way. It does not do to teach or to learn subject-specific methods. They should also be turned into topics and students should reflect on them. This can be achieved through a diversified methodological access to a topic, comparison and making it thematic. That way, learning becomes more co-operative and student-oriented, and it is less direct. In secondary II it may lead to a form of science propaedeutics. It is obvious, that this in particular is an argument for cross-curricular teaching - especially in secondary II (Acker 1977).

Tenorth approaches the argument from a different angle, in that he understands the subject canon as “a structure of certainty” (Tenorth 1997, p.20). In transferring Popper’s concept of falsification, the canon does not become comprehensible by what it is but by what it excludes, “because the canon is a kind of mark defining for those, who are allowed to learn it, what they are not allowed to learn” (Tenorth 1997, p. 20). According to Tenorth, cross-curricular instruction becomes meaningful exactly because it turns the exclusion into the topic.

> “At this point I dare say what cross-curricular learning is, namely that it turns the certainties of school knowledge itself - which are usually and quite self-evidently transformed - into the topic of learning at school.” (Tenorth 1997, p.20).

3.2.6 Cross-curricular Teaching as a “Counterpart” to Specialization

The reflection about subject-specific methods, made possible through the transgression of subjects, also makes it possible to create an awareness of the limits of specialization. This is interesting insofar as, historically, science has always been geared towards specialization and with good reason, as the following excerpt about the historical view of science shows:

The origins of the scientific disciplines, including those of the school subjects, go back to Platonic-Pythagorean philosophy. In the ancient faculties, one distinguished between two groups of subjects: those subjects that worked out the “true laws and relative proportions of the cosmos” included arithmetic, geometry, astronomy and music and the subjects of “logical thought, judgement and argument” which included logic, dialectics and rhetoric (Mainzer 1993, p.19).

The discussion on the concept of science was particularly influential in the division of the subjects. According to Aristotle, only purely theoretical subjects counted, such as mathematics, physics, inclusive of all disciplines that described nature, and metaphysics. The concept of science in modern times, however, deviates from the prerequisite that it has to be theoretical and acknowledges, e.g. experimental physics with its mathematical and technological methods is recognized as a science. Kant had a particular influence on the division of disciplines in Humboldt’s university. His division of disciplines was based on the terms “usefulness” and “truth” with philosophy marked off. The useful faculties were theology, jurisprudence and medicine (upper faculties), while it was to be the task of philosophy (lower faculties) to present the truth for the use of and also the control of the upper faculties (Kant 1968). Different paths to the recognition of truth led Kant, additionally, to divide the philosophical faculty in the fields of “historical recognition” (history, humanism with the natural sciences, scholarly acquisition of languages, description of the earth) and the fields of “pure logic” (pure mathematics, philosophy, the metaphysics of nature and of manners) (Kant 1968, Mainzer 1993, p.21). Kant’s definition of the philosophical faculty is an important example of trans-disciplinariness (cross-curricular teaching) in history, that fundamentally characterized the spirit of Humboldt’s university.

In the 19th century, the philosophical faculty could not be maintained. Developments in the subjects, in particular with regard to experimental methods, led to a delineation of the natural sciences (and mathematics also), however, with philosophical-theoretical accompaniment. While Hegel’s philosophical approach did not consider the natural sciences to be scientific, mathematics is according to Compte’s positivistic view of the sciences, the highest scientific discipline, followed by physics, chemistry, biology and sociology (Mainzer 1993). Compte’s classification of the disciplines according to their positivistic degree excludes all forms of inter-disciplinary activity, as this would contradict the natural limits of the subjects, that the categories separate) Vonéche 1993).

Progress in the other faculties led to the establishment of the humanities with their own methods. Dilthey's concept of the humanities is a very extended one and comprises all disciplines whose object is "the historical-social reality", including language, art, religion, as well as education, society, law, economy and technology. This division failed to survive, however, as the rapid progress of the individual disciplines with their own methods and contents, but also the social development, made discrete fields of education necessary. The industrialization in the 19th century, in particular, required a discrete training of engineers. A characteristic of the universities, that originated from the dynamic development of the sciences, was the still existing "pluri-disciplinariness" or "multi-disciplinariness" with many disciplines existing side by side, where at best a linear exchange of individual information is practised (Vonéche 1993 according to Piaget, p.116, Mainer 1993, p.23).

In more recent times, pragmatism has replaced the search for the limits of disciplines. Multi-disciplinariness is discussed all over the world on the background of general environmental and humanitarian problems. On the one hand, multi-disciplinariness enables specializations that may lead to particular scientific findings and developments, necessary for the solution of problems. On the other hand, the global problems of mankind require linked thinking (Cf. 3.2.4). The need for cross-curricular questions and their joint solution is accounted for in the scientific community through the promotion of inter-disciplinary projects, the establishment of inter-disciplinary centres (Arber 1993), but also through the endeavour of imparting cross-curricular thinking to students in their training. Inter-disciplinariness in research is, however, today of a rather reactive nature, in that it is carried out primarily in those areas where (global) problems have to be solved, that individual sciences can no longer cope with.

3.2.7 Cross-curricular Teaching as an (additional) Opportunity for Learning Important Basic Mental Techniques

This objective is not to be seen independent of other objectives – because every objective requires certain basic mental techniques – and equally concerns the objectives of maths teaching (Zech 1998). Since the objectives are not subject specific, it is logical to try and achieve them through cross-curricular questions (Cf. annotations to individual points). However, it remains an open question at this point, in how far cross-curricular teaching can really achieve these goals better than pure subject teaching. Because of its structure, cross-curricular teaching is possibly more concerned with the higher levels of basic mental techniques. (The following collection was taken from Zech 1998, p. 56ff):

- Comparing (Cf. 3.2.5)

  Grasping differences and common features:

  Cross-curricular/subject-integrative teaching promises to compare the terms and methods of different subjects
- Ordering (Cf. 3.2.9)

  Collecting, respectively, establishing a rising or falling progression with regard to one or more criteria:

  Cross-curricular/subject-integrative teaching promises, e.g., to order terminological experiences from different fields.
- Abstracting

  Collecting essential and neglecting inessential characteristics for a concrete objective or question:

  Cross-curricular/subject-integrative teaching promises to support this process through the insight that the approaches of different subjects or a cross-curricular problem cause different processes of abstraction.
- Generalising

  Collecting common, and at the same time, essential characteristics and forming classes:

  Cross-curricular/subject-intensive teaching promises to support this process in that the co-operation of several subjects validates new fields and shows new applications.
- Classifying

  Assigning an object to a class or relating classes:

  Cross-curricular/subject-integrative teaching promises a variety of areas where classification can be applied.
- Substantiating respectively specializing

  Transferring and applying the common to the special features and the individual features:

  Cross-curricular/subject integrative teaching enables a review of one's own subject, such as in complete orientation.
- Formalizing

  In a general sense, as an encoding of information, but also as mathematising:

Cross-curricular/subject-integrative teaching offers a lot of material through situational applications.

- Finding analogies

  Establishing analogies between different areas of phenomena:

  Cross-curricular/subject-integrative teaching seems to be predestined for this, since it offers various areas of phenomena through the participation of different subjects.

3.2.8 Cross-curricular Teaching as a Field in which to Experience the Social Reality of Science

While student orientation and the demand for holistic learning are essential arguments for cross-curricular teaching in primary and secondary I (and II), the demand for teaching the social reality of science mainly concerns instruction in secondary II. Cross-curricular teaching offers itself for this, because it may symbolize – for a number of mankind's problems – a counter-weight against specialization and it contains the possibility to thematize subject specific methods. This was already addressed in 3.2.5 and 3.2.6. To be more precise: It may be an objective of cross-curricular teaching to clarify the relationship between subjects - typical of research. (Huber 1997, p.65):

- Complementary: One view or experience complements the other
- Concentric: Several views address a common subject or problem area
- Contrastive or dialogical: one view or experience contradicts another, makes it relative; it is a matter of mutual understanding and translating
- Reflexive: with the help of other views, consciously taken, one's own or that of one's subject is reflected upon.

The aspects contain, at the same time, the social component of scientific work. It may be an objective of cross-curricular teaching to make students experience this, e.g. if general questions in project work are worked in social interaction (work groups, study groups, planning, communicating, discussing the results etc. (Cf. also 3.2.10).

3.2.9 Cross-curricular Teaching as an Aid in Integrating and Structuring Learning

As a rule, the basis of today's education is the instruction in individual subjects. Students learn in a subject-specific way. However, school also has the duty to care for the children's and the young adults' integration in the professional, social and cultural reality. In order to unlock life's reality, subject elements have to be connected, because reality is holistic (Cf. Wagenschein's quotation in 3.2.4). Cross-curricular teaching offers the opportunity to integrate and structure these learning experiences (Landesinstitut für Schule und Weiterbildung , Soest 1995; cf. also the argument for linked thinking in 3.2.4).

3.2.10 Cross-curricular Teaching as a Field for the Improved Practice of General Competences

Competences are personal conditions, knowledge and experiences that determine our behaviour and our actions. Competences are not directly visible but can only be deduced from certain repetitions in a person's behaviour (Flammer 1999). In the following model, four competences are distinguished (the first three, formulated by Habermas, are complemented by a fourth, formulated by Kreft, Fritzsche 1999, p. 38 ff):

- a cognitive competence, that concerns the recognition of natural laws, if – then-relationships (dealing with objects)
- an interactive competence, that concerns inter-personal actions and the standards that they are judged by (dealing with subjects)
- a language competence, that concerns the rules of how words, sentences and texts are formed, related to reality and understood
- an aesthetic competence, that concerns man's capability to experience something and to symbolically express his/her subjectivity.

Social developments can be shown to have a clear influence on the field of human competences. The enormous progress in subjects, such as the technological developments of the last century and the growing participation in it by the population, e.g. in the use of the automobile, the internet and the mobile phone, all of these point to an imbalance in the distribution of competences among people. Various US-American studies, indeed, show a predominance of the cognitive competence (Fritzsche 1999). However, a purely cognitive alignment is socially unacceptable. School also has to help develop mature personalities with social responsibility in a democratic society, which requires taking into account all competences. In addition, a person's cognitive competence gains further in personal and social importance through the ability to co-operate and to communicate.

With regard to cross-curricular instruction, the competence model leads to the following considerations:

> There is no unambiguous allocation of subjects and competences. Promoting competences must be seen as a joint task of all subjects, with each subject making its own contribution to the field of competences. This can only be achieved through the respective different aspects (alien aspects). Cross-curricular teaching allows us to approach this target jointly. The promotion of individual competences may be strengthened by this and may be achieved in a more target-oriented way.
>
> On this background, the competence model was variously used to criticize the existing curriculum. One consequence of the criticism was, e.g. the replacement of the subjects by “fields of experience” in the Bielefeld laboratory school.
>
> Instruction in subjects can be particularly assigned to the cognitive competence. In that way, the competence model confirms the importance of a division in subjects, respectively, of working in subjects.

Instruction has to create situations, in which competences can be acquired. With regard to the non-cognitive competences, a number of methodological suggestions have been made, such as product-oriented, interactive, student-centred and, in particular, holistic teaching with its various methods (Cf. 3.2.2). These methods can also be used in subject-specific teaching. However, cross-curricular teaching, due to its variety of contents and its methodological possibilities as well as forms of co-operation, seems particularly suited for the use of such methods and therefore predestined to promote competences generally. Huber gives the following reasons (Huber 1997, p. 24):

> “If we imagine cross-curricular instruction, in which students of different specialization meet and have to impart their knowledge mutually, in which they mutually answer questions as experts or have to co-ordinate their various capabilities in projects, then we have got a situation, in which communicative, co-operative competences, messaging and self-regulatory competences have not only been preached but made situational and could actually be experienced.”

3.2.11 Cross-curricular Teaching as an Opportunity to Develop Ways to Deal with Heterogeneity

> "Starting from the assumption that ever increasing differences in the learning conditions, the educational biographies, the cultural backgrounds, or even in the ages of the students, their professional experiences or the experiences they have made during their schooling, come to bear on our schools … the task of dealing with these differences is a task that is only confronting us in its totality in the near future. Here, cross-curricular teaching with its special possibilities to access the problems methodologically and from a content point of view, offers an enormous opportunity" (Huber 1997, p.23).

The problem Huber addresses in his quotation, does not only concern the students' school life but the total social life. In particular, a society with great social variety requires a well trained way to deal with heterogeneity. Dealing with heterogeneity becomes problematic if it is not seen as an enrichment but as a disturbance, if there is a clear division between the national and the alien culture. From a sociological point of view, one's own culture and the alien culture are interrelated but changeable and most of all relative terms. The concept of the alien is always connected with social exclusion. "What is considered 'alien' depends on the image the respective society has of itself and of its understanding of who makes up the 'we' group, of its anxieties, its ideals and its patterns of perception (Eickelpasch 1199, p. 106). A change in the patterns of perception may lead to a situation, in which what is alien is no longer perceived as alien and is no longer excluded. To achieve this, should be an educational concern.

In the cross-curricular model, alienness is an essential element but the relativity of the term is also evident here. What, from a subject's point of view, is an alien aspect, becomes an idiosyncratic aspect, if viewed from the co-operating subject (Cf. model). One can safely assume that alien-ness, such as a German language teacher's fear of mathematical formalism, forestalls or inhibits co-operation. In the cross-curricular model, alien-ness is, however, explicitly called an enrichment. Without alien-ness there would be no motivation for cross-curricular teaching. Cross-curricular teaching then offers the special opportunity to experience alien-ness as an explicit enrichment (Cf. also to 3.2.8).

3.2.12 Cross-curricular Teaching as a Contribution to General Education

General education is a very comprehensive term, characterized by varying emphases in different educational theories. In classic educational theories, there were three criteria (which, in fact, clearly favour cross-curricular teaching (Jank, Meyer 1994, p 175 f.):

- General education is *education for all* without regard to provenance, parentage, social class or fortune.
- General education is *comprehensive education*, i.e. an education that promotes an individual in the greatest possible way – not only in special fields or with respect to his/her later profession – but in all his/her capabilities.
- General education is education "in a general sense", i.e. in the comprehensive context of the world around us.

In the present discussion about education, two directions can be distinguished: One direction defines general education via a canon of subjects, contents, knowledge, competences etc. . The other direction identifies methods and competences that man needs to live, survive and work (Jank, Meyer 1994). In contrast to these, there is Klafki, who rejects the formulation of canons for general education. For him, the central issue is the solution of present and future key problems (Klafki in Jank, Meyer 1994, p.177):

- ”My thesis is as follows: Education, respectively, general education … means to have gained a consciousness of the central problems of our common present and predicable future, transmitted through history, an insight into our collective responsibility for such problems and the willingness to face them and take part in their solution…"

In paragraph 3.2.13, the contribution, cross-curricular teaching can make to general education, will be discussed.

3.2.13 Cross-curricular Teaching as a Special Opportunity to Deal with Topical Issues

In a world, growing together more closely all the time, catastrophes or extraordinary events are becoming more and more likely. This should not be a no-no for schools – on the contrary, they should address topical issues (This also concerns the general education aspect in 3.2.12). Such issues are rarely subject-specific. As an example, an accident in a power station is related to physical (cause), chemical, biological (effect), but also political, economic, geographical, sociological aspects, and, last but not least, to mathematical aspects. Cross-curricular teaching offers the opportunity to comprehensively understand the topical event. This implies, however, that cross-curricular teaching can be effected spontaneously. The organizational prerequisites would have to be clarified beforehand. As shown in the magnet and star mode, the colleagues from different departments would be able to recognize the relevance of it for their departments instantaneously and be able to make their contributions.

3.2.14 Cross-curricular Teaching as a Special Opportunity to Disclose the Importance of Interdisciplinary Co-operation in the Solution of Problems

The importance of interdisciplinary learning and linked thinking for the solution of the global problems of mankind has already been addressed at various points. However, interdisciplinary learning can also be of importance for the solution of technical questions. Zeidler (1998) shows this very impressively in his contribution "The fascination of the mutual effects between mathematics and the natural sciences" (my translation). Mathematics, e.g., allows us to integrate the myriad of natural phenomena in a few basic equations; and the collaboration between mathematical and physical research programmes can lead to fascinating insights: The realisation "Energy equals Curvature", f. e., resulted from physical research into the energy concept and mathematical research into the curvature of geometrical forms. However, in order to bring together such research areas, an intensive dialogue is necessary, for which the foundations can be laid in school. Zeidler concludes (Zeidler 1998, p. 335):

> "It is an important task for the future to train young people in school and at universities who are prepared to and able to enter into a dialogue with different scientific disciplines."

Cross-curricular teaching can be seen as an opportunity to highlight its importance at school level. One objective of cross-curricular teaching may be to make students aware that "the solution of problems is facilitated, if they are structured along subject aspects with the aim of bringing together the results in a cross-curricular way" (Landesinstitut für Schule und Weiterbildung, Soest 1995).

3.2.15 Cross-curricular Teaching as an Opportunity to Solidify Subject Knowledge

The basis of this objective is the idea that, through the cross-curricular problem, questions can be approached that otherwise remain undisclosed, respectively cannot be dealt with in the same complexity. Thus, in a German language class, topics of comprehensive orientation are better suited to a discussion than purely literary or linguistic questions. For maths teaching this has to be seen in the context of the rationale for applied mathematics and the importance of mathematical model formation. It is obvious, however, that cross-curricular teaching that is designed to delve especially deeply into a subject, has to have long subject specific phases. In project orientation, this could be done in work groups. However, this objective is to be examined separately. For maths teaching, the following applies:

> “The concentration on situational aspects, that can be treated mathematically, … may collide with the interest in other dimensions of the problem” (Jablonka 1999, p. 65).

With regard to a specific subject, this additionally results in the following objectives:

3.2.16 Cross-curricular Teaching as an Opportunity to Experience the Particular Importance of a Given Subject

According to the cross-curricular/subject-integrative model, there are two types of subject orientation. With regard to the argument in question, the x-orientation is of particular interest. In x-orientation subject X is the starting point. In co-operation with subject F, X is used (and possibly worked out) to introduce, work out, explain, describe connections in F, to create objects in F or to structure F. On the surface, it is about teaching content from F. However, this content is developed or deduced with the help of X. That way, the importance of X in contexts outside X is made clear. Its importance is enhanced in the co-operation with various very different subjects, respectively in connection with topics of comprehensive orientation, that generate personal concernment.

3.2.17 Cross-curricular Teaching as a Special Opportunity to Tackle the Problems of a Particular Subject

With the publication of the results of the TIMSS-study (Third International Mathematics and Science Study) and as a consequence of the PISA-study, German maths and language instruction was exposed to public criticism. A detailed analysis has shown, however, that the criticism was only relative in some points (Cf. for maths Blum Neubrand 1998, Wiegand 2000, Weigand 1997); however, certain deficits have to be admitted:

> "The deficits in the achievement of German high school student compared with students from countries with higher student achievement are particularly obvious in tasks that test mathematical-natural science understanding, demand a flexible application of learned material or offer an unusual problem constellation" (Baptist 1998, p. 5).

The weaknesses show up

- if a flexible connection of several subject areas is required, i.e. of geometrical tasks to calculations,
- if several steps have to be combined to solve a task,
- if different aspects of a topic are addressed simultaneously,
- if the use of unaccustomed material is required, i.e. terms not used in the accustomed contexts,
- if the construction of complex models is expected" (Neubrand, Neubrand, Sibberns 1998, p.26 in Wiegand 2000, p. 95).

Organisational and methodological consequences have been drawn from these results, such as more frequent use of internal differentiation, more frequent change of methods, lower teaching loads for teachers (Japanese teachers only teach 16 instead of 25 lessons a week) etc. (Weigand 1997). Ulm formulated 15 points, including varying the formulation of the tasks, open questions, but also securing basic knowledge, cumulative learning, setting tasks applicable to meaningful contexts and tasks requiring subject-integrative work (Ulm 2001).

4 The Implementation

The abundance of objectives and arguments for cross-curricular instruction may create the impression, that teaching the core of a specific subject is meaningless. This impression is problematic and wrong. It has already been referred to in some places.

On the one hand, the objectives mentioned do not at all comprise all teaching objectives. On the other hand, they only make a limited and quite general statement about the actual value they have for the subject concerned. If, how and to what degree the advantages are achieved, must be seen in each individual case.

In the implementation of cross-curricular/subject-integrative teaching in school, the model can be used as a basis for decision making. This assumes, however, a comprehensive survey of the subjects involved and their connection, as well as a survey of the objectives, that can be reached or that are aimed at in the co-operation (see section 3).

Thus, in parallel work and parallel orientation, it should be guaranteed that all students in the group are actually attending instruction in the parallel subjects. This may be difficult, in particular at the secondary level where specialization is the norm in Germany. A suggested solution is the "institutionalized coupling model" in which it is mandatory for the students to choose a certain subject combination (Landesinstitut für Schule und Weiterbildung, Soest 1999).

Additionally, freedom in the choice of methods must be possible, which in project orientation allows the use of the respective repertoire of methods, including group work, self-study and possibly extra-curricular events (excursions, study days, performances of plays), or which, in the reflection on subject-specific methods, chooses alien methods that are really applicable (experiments taken from physics in maths instruction). It becomes clear that there will be a greater demand for special classrooms allowing spontaneous use, for special rooms for subject- integrative teaching, respectively for extra-curricular days.

> "Principally, one must ask the question, in how far the … existing principle of allocating rooms according to the learner groups must be reconsidered, if and when it makes sense, or is even indispensable in cross-curricular teaching, that some rooms should be especially equipped for subject- or project-oriented teaching. This could make the use of existing aids easier and allow the creation of a collection. In addition, it ought to be consid-

> ered whether rooms for self-study are needed." (Landesinstitut für Schule und Weiterbildung, Soest 1995)

In addition, freedom of planning must be guaranteed by all stakeholders, so that instruction can be spontaneous (example-orientation at level 1) or prepared long beforehand (course-oriented at level 4).

Long term planning is characterized by the fact, that cross-curricular/subject-integrative teaching is preceded by a phase filled with comprehensive theoretical work. This basis can lead to the arrangement that cross-curricular teaching is part of the curriculum or part of the school's program. In that sense, the planners need not be identical with the co-operating teachers that implement it later on, however a design science approach is warranted to ensure planning, communication, implementation and research in multiple phases. In a mode of replacing subjects, the long term planning can refer to the development of a focus for the students'entire schooling, that is constantly renewed, taken up by other subjects and dealt with in greater depth. Certain periods at various levels could be allocated to cross-curricular teaching (Landesinstitut für Schule und Weiterbildung, Soest 1995). In a subject-complementary form, the long term planning may refer to the development of new integrative subjects, such as the subject natural science. Long term planning implies a high degree of subject competence, but also an informed overview of all school levels. Long term planning, that is integrated into the curriculum, has the advantage that a new form of period, room and staff planning can be introduced for the time that periods are adjourned, which also allows the freedom to try out new methods. However, this pre-supposes, that all of these subjects are co-ordinated in the curriculum. *I argue that the subject complementary form avoids this problem and can be largely integrated into the given arrangement.*

In medium-term planning, which can of course be based on curricular suggestions, the co-operation is usually pre-planned before the start of the school year and only concerns part of the staff. This requires consideration in the timetable, where team teaching or possibilities for substituting during the respective time span, play a role. To increase flexibility, the occasional use of double periods, marginal periods and successive periods for co-operating teachers, respectively free periods are suggested (i.e. Landesinstitut für Schule und Weiterbildung, Soest 1995).

It becomes clear that cross-curricular/subject-integrative teaching is easier to arrange through long-term, central planning than in medium-term planning. It is medium-term or even short-term planning, however, that makes creativity and new concepts possible, and it also allows teachers to respond to topical events. Mid-range planning is also desirable. Here, the introduction of a reservoir of marginal periods in the timetable may help, which can be used by all subject teachers spontaneously and temporarily for cross-curricular teaching, and which can replace regular teaching for a time.

To conclude, the problem of performance measurement, which is a special topic in project-orientation, will be addressed briefly. In addition to classroom tests, reports, work progress reports, presentations or papers are suggested (see Landesinstitut für Schule und Weiterbildung, Soest 1995).

5 Final Remarks

This paper shows that although there is no single type of cross-curricular/subject-integrative instruction with a single set of objectives, there are techniques to make cross-curricular/subject-integrative teaching multi-layered, differentiated and highly variable. The conceptual model, that was developed, reflects this complexity.

> The four forms of co-operation and their respective three or two co-operative approaches, the three contact forms, the four interest orientations (disregarding a differentiation between orientation towards common and alien features) and the two respectively three forms of interest orientation already result – purely mathematically, without considering subject aspects and topics - in 200 different possibilities!

In the implementation of cross-curricular teaching, this complexity must be considered, in that the layout takes into consideration decisions made on the background of the model. If and in what form cross-curricular teaching seems suitable for the classroom, has to be examined on a case by case basis. It ought to be considered here, that cross-curricular teaching should always be aimed at enrichment. The model, presented in 2, offers a basis for decisions and evaluations with the background and framework of the objectives in 3, in that it presents the respective components of the model that are applicable to individual designs.[10]

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[10] The particular value of the model is that it allows a theoretical foundation as didactical and methodological groundwork for the practical implementation of cross-curricular teaching with respect to special subjects. We have done this groundwork for cross-curricular maths teaching. In particular, the possibilities for co-operation with subjects such as Physics, German and Information Technology were examined (Beckmann 2003 a, b, c, d).

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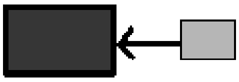
Cooperation Forms for Cross-Curricular Lessons

Short overview, according to *Model Beckmann* 2003[11]

Topic and Major Subject – related form (TM - Form)

Aspects (contents, methods,..) from scientific subjects (physics, chemistry, biology..) used in mathematics lessons.

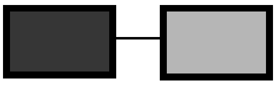


Organisation: Initiative: mathematics teacher,
Communication with colleagues teaching scientific subjects,
Colleagues support mathematics teacher

Parallel Topic - related – Form (PT - Form)

School year

Mathematics	**Physics**	**Chemistry**	**Biology**	**Geography**	…..
Aspects of the theme concerning mathematics learning	Aspects of the theme concerning mathematics learning	….	….	…..	



Organisation: Initiative: one or more teachers
Communication and common planning of the school year or parts of it,
Parallel teaching of the same theme and permanent exchange between the teachers during this period

Parallel Planning – Form (PP - Form)

Possible example

<table>
<tr><td colspan="4">Mathematics – physics – chemistry – biology
Introduction – approaching the theme (in common)</td></tr>
<tr><td>Mathematics
Special aspect of the theme</td><td>Physics
Special aspect of the theme</td><td rowspan="3">Chemistry
Special aspect of the theme</td><td rowspan="2">Biology
Special aspect of the theme</td></tr>
<tr><td colspan="2">Mathematics and Physics
Mathematical modelling of the physical phenaomena</td></tr>
<tr><td colspan="2">Mathematics – Biology
Using mathematics argumentation in biology</td><td rowspan="2">Physics
Deepening of the physical aspects</td></tr>
<tr><td>Mathematics
Deepening the mathematics aspects</td><td colspan="2">Biology – Chemistry
Discussing common aspects of the theme</td></tr>
<tr><td colspan="4">Mathematics – physics – chemistry – biology
Results (in common) and summary</td></tr>
</table>

Organisation: Initiative: one or more teachers
Permanent communication and common planning before and during teaching the modul, partly: common teaching according to the needs of the theme

Joint Planning – Form (JP - Form)

Organisation: Initiative: one or more teachers
Team teaching: **All subject melt together to one subject!**
Possible: project-oriented teaching with subject-oriented project parts.

[11] Beckmann, Astrid (2003). Fächerübergreifender Unterricht – Konzept und Begründung, Hildesheim, Berlin (Franzbecker Verlag), www.sciencemath.ph-gmuend.de