INTER-TETRA - A GERMAN-VIETNAMESE PROJECT 
COMBINING PHYSICS AND MATHEMATICS DIDACTICS

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Abstract: The advantages of interdisciplinary teaching and learning in school have been discussed for some time. However, in order to exploit the full potential of this approach, interdisciplinary teaching and learning must go beyond a mere sequence of special content. This is accompanied by the need for appropriately trained teachers, whose training should follow a holistic approach, especially in the context of their university education. The project “Inter-TeTra” is such an approach and it is expected that the project will contribute to the further development of competences for subject-related teaching. In this paper the basic idea, the planned course of the project and the first studies on the theoretical basis will be outlined. In order to obtain a valid selection of topics from both subject didactics, a comparative content analysis of German, Vietnamese, French and anglophone work on didactics is carried out in the first step. It is expected that such an intersection will contain topics of great sustainability and high educational relevance.

Keywords: Developing country project, Interdisciplinary approach, Physics-mathematics relationship, Teacher training curriculum development.

1. INTRODUCTION

The main objective of the OECD (Organisation for Economic Co-operation and Development) and the education authorities in Vietnam is to reform the education policy by developing a more competence-oriented curriculum (Communist Party of Vietnam, 2013). Germany has two decades of experiences with these types of reforms. The adjustments to the curricula since the moderate results of German students in the TIMSS and PISA studies show the opportunities and challenges of such reforms (KMK, 2004) and the importance of teacher training for the success of school reforms (Hattie & Beywl, 2013). The cooperation between German and Vietnamese teacher educators offers the opportunity to avoid well-known problems in implementing such revisions. In addition, the collaboration can generate new knowledge out of the cultural and structural differences between the two societies, allowing for the further development and implementation of novel and distinctive curricula.

2. LITERATURE REVIEW

2.1. Challenges of Interdisciplinary Learning and Teaching

In addition to a number of advantages, the approach of interdisciplinary teaching is also accompanied by a number of challenges (Defila & Di Giulio, 2002, 24). This applies both to school teaching and to the networks of various subjects at university level. One of these aspects is the combination of the different specialist methods. This is certainly a minor problem in the natural sciences. On the other hand, if we think of a link between the natural sciences and the humanities, the gap to be bridged here is much wider.

Communication problems are to be mentioned immediately after the specialist methods. These often also result from the historically evolved definitions within the individual technical cultures. Even without foreign language influences, translations must always be done, and an agreement must be reached with regard to the terminology used.

Less directly related to school teaching is a third challenge, which can be described as the search for common research topics. For a combination of mathematics and physics, the hurdles here are lower (see below) than may be the case with other subject combinations. Nevertheless, corresponding topics must be found and again the possible differences regarding the contents of the terms must be worked out. This is both a challenging and enriching task.

The consideration of prejudices and the handling of group-dynamic processes are not a specific problem of
the subject connection. However, they also represent a possible problem area of interdisciplinary cooperation. Above all, however, the common goal is to further develop interdisciplinary teaching and to ensure its quality. Because, up to now, it has to be stated too often:

“Some [teachers] also feel challenged to an extent no longer justifiable because they have studied for the most part one, but at most two of these subjects and cannot imagine this new subject in any other way than from biological, chemical and physical set pieces in an additive manner.” (Rehm, 2008).

From a school perspective, the biggest challenge by far is certainly the fact that the teacher has to teach an unknown subject. For example, the teacher of mathematics will have to use kinematics and mechanics as a context to clarify the meaning of derivations (Danckwerts & Vogel, 2006). Even independently of intensified interdisciplinary approaches, teachers are necessarily dependent on dealing with the essential problems of related subjects. An example for this case is the physics teacher who is confronted with his students’ learning difficulties in converting equations or solving integrals (Strahl & Thoms, 2012).

At this point, a rupture becomes visible that threatens to separate university teacher training from school reality. The organization of the training is strictly separated according to subjects. This finding applies to the majority of the worldwide courses of study (Bröll & Friedrich, 2012). On the one hand, this system has grown historically, and, on the other hand, it is based on the teaching of content according to its own specialist system. The school approach, on the other hand, requires a close integration of different subjects that go far beyond the possibilities of the current system of education.

Based on these problem areas, the goal of interdisciplinary teacher training can be formulated: To make interdisciplinary teaching and learning in schools be more than the additive juxtaposition of elements of knowledge from different disciplines (Wellensiek, 2002, 80), the universities should implement holistic concepts for integrative teacher education.

2.2. Problem-based learning in authentic contexts

It is immediately obvious that real problems do not stick to disciplinary boundaries. Thus, even school lessons that are oriented towards real contexts cannot be organized within the classical subjects. In the following, a few selected examples will show intersections between mathematics and natural sciences. It should be noted that this list is arbitrary and can be extended at will. Also, there is no natural obligation to draw a line between mathematics and the natural sciences on the one hand and social sciences on the other.

Example 1: Mathematics and Astronomy

A solar eclipse can be used as an example to develop a wide variety of geometric facts (Krause, Stoffels, Witzke, 2018). In addition to the pure study of formulas, the lessons can also include practical aspects in the form of the construction of a “solar eclipse box”. The experiment allows, with the use of elementary geometry and linear algebra, the construction of the constellation of celestial bodies that lead to a solar eclipse.

Example 1: Physics and Geography

The emergence of tropical storms, such as typhoons, is a complex topic that can only be comprehensively explored by combining different subjects (Ruess et al., 2008). This can be achieved by combining geography and physics. The direct application results from the occurrence of storms along a zone near the equator. However, an analysis limited to the geographical perspective cannot provide any reasons for the conspicuous distribution of the phenomenon on the earth’s surface. The concrete conditions caused by the temporal variances can also only be detected by physical means. The teaching becomes much more multi-faceted through the inclusion of physical model experiments. For example, the stratification of warm and cold water due to differences in density. At the same time, the abstract physical aspects (e.g. Coriolis force) benefit from the direct reference to a motivating context.

Example 1: Chemistry and History
In the third example, a possible link between a natural science and a social science is presented. The mining and processing of copper has been taking place since the earliest times. However, the purely historical perspective on mining regions and transport routes do not yet allow a comprehensive understanding of the state of the art of the “Copper Age”. The extension by chemical experiments for the extraction of pure copper from copper ores allows precisely this insight into the fate of the people of earlier times. At the same time, from the point of view of chemistry, the subject content is embedded in a broader context and can therefore have a more motivating effect.

Using the synergies between the subjects

In addition to the interdisciplinary treatment of complex questions, there are further advantages to the inter-disciplinary teaching. In this way, the synergy effect can be used at some points. As part of the deduction of the lens equation, for example, a connection with mathematics lessons is possible. This gives the intercept theorem a meaningful context and a direct possibility of application. Mathematics can thus break out of the role of a mere tool of physics and the interdependencies of the subjects become visible.

The selected example of lens equation and intercept theorem is one of the possible connections between mathematics and physics, which is also used by students as part of teacher training at the University of Siegen (see section 4 for details).

Preliminary conclusion

The previous approaches for interdisciplinary teaching, as well as the examples presented here, represent valuable and most welcome contributions to the further development of teaching. However, the project presented here pursues a different approach, which has so far been taken into account much less frequently. The main difference between our approach and others is that we start much earlier. By this we mean that our courses start before the practical implementation of the respective combination of subjects in the classroom. Before our approach is presented, however, the relationship between the school subjects of mathematics and physics must be considered. The following section, therefore, explains why the project presented in this article concentrates on the relationship between mathematics and physics.

2.3. Physics and Mathematics from the Perspective of Interdisciplinary Teaching and Learning

Of course, mathematics and physics are different sciences. This applies to both methods and content. It may seem appropriate to assume for an initial characterization that mathematics works deductively, and that physics makes use of the inductive method. The details of the considerations presented here can be found in the contribution of Krause (2018) to this conference.

Nevertheless, the parallels between the two subjects have been discussed for years, including the philosophy of the natural sciences (e.g. Sneed, 1971). A closer look at the nature of the natural sciences reveals epistemological parallels between mathematics and physics that have developed over time. Since Galileo Galilei’s time, the realization has been established in physics that inductive generalization alone does not lead to new knowledge. Since then, the epistemological repertoire of physics has been extended to include the method of deductive reasoning (Simonyi, 2012, p. 215). One model for the physical cognitive process is Albert Einstein’s so-called EJASE process. For details please refer to the literature (Cf. Holton, 1981; Kuhn, 1983; or Krause, 2017). At this point, only the following aspect

![Diagram](source: leifophysics.de)

**Figure 2. The derivation of intercept theorems is a suitable reason for linking mathematics and physics (source: leifophysics.de)**
is relevant to us: According to Einstein, physical ideas are generally based on the researcher’s intuition.

Figure 3. Einstein’s original sketch of his “EJASE”-process

Modern mathematics, on the other hand, relies on the internal consistency of its foundations and the logic of the derived statements. However, if mathematical statements are interpreted as statements about reality, mathematics quickly loses its certainty. Einstein formulated it as follows: “As far as the laws of mathematics refer to reality, they are not certain; and as far as they are certain, they do not refer to reality” (quoted Hempel, 1945).

In Germany, since about the 1980s, efforts have been made to introduce such application references into mathematics lessons. The following dilemma occurs: While some teachers would like to convey an abstract-formal mathematical theory, their pupils actually learn an empirical-representational theory about illustrative means (Schlicht, 2016; Witzke & Spies, 2016). Students and teachers then might have different conceptions of mathematics in one classroom: the theories of the pupils are ‘physical’ theories in the sense that phenomena of reality, namely, the visualization, are described and explained. The common feature between math and physics, however, is their empirical character: it is about describing and explaining empirical (physical) phenomena (Krause, 2018). However, this is not to express that the formal-abstract contents do not have a clear value for mathematical education. As a rule, however, the student’s view is concrete and representational.

So, our assumption is that mathematics and physics, as practiced at school, can both be seen as empirical sciences. Our approach assumes that disciplines that have a comparable way of acquiring knowledge also have corresponding parallels within their didactics and methodology. This assumption is supported by findings on large intersections within the didactics of both subjects, which are discussed in more detail in Section 3.2. It follows that the combination of subject didactics is both justified and promising.

3. METHODS AND RESULTS

In the following section we will describe how innovations can be initiated based on previous findings on interdisciplinary teaching and the epistemological parallels between the two school subjects. First, one of several projects of the University of Siegen will be briefly presented, in which this approach has been tested in practice. Finally, the structure of the new project Inter-TeTra is presented, which represents a further development of the approach.

3.1. Projects in Siegen

Despite many benefits of interdisciplinary teaching and learning at school, the teacher training at Germany as well as Vietnamese universities are still largely organized in a discipline-oriented manner. The first phase of the teacher training should clarify the advantages and tackle the challenges of an interdisciplinary education. The inadequate fit of non-integrated teacher education with the requirements of interdisciplinary teaching (Bröll & Friedrich, 2012) is repeatedly cited by teachers in schools as an objection to integrated instruction (Jürgensen, 2012; Rehm, 2008). The frequently discussed difficulties in connection with non-specialist teaching should also be considered against this background (Porsch, 2016). Appropriate didactic concepts have already been developed at some universities (Witzke, 2015; or Krause & Witzke, 2017). The University of Siegen works currently on interdisciplinary education projects such as MINTUS, FiMaPDi and InForM PLUS (see Figure 4) (Krause, 2017 or Holten & Witzke, 2017). For this purpose, the subjects of mathematics and physics seem to be the most appropriate since these subjects have numerous epistemological parallels (Krause, 2016). First approaches for establishing subject-linking lessons already exist in Vietnam (Nguyen and Thanh, 2014; or even Nguyen, 2015). In contrast, the present project does not initially focus on interdisciplinary teaching in Vietnamese schools but starts earlier by adding an interdisciplinary module to teacher education. In this way, the connecting element in the subject-linking lessons of the future is not only the common subject of instruction (which is viewed from the perspective of different subjects) but rather the embedding of lessons in the comparative discussion of didactic theories in the participating subjects from the very beginning, with the goal of concretization and implementation in the Vietnamese curricula. This approach is an innovation especially for Vietnam,
where teacher training is currently rather isolated and compartmentalized. While the modern application-oriented teaching of mathematics looks for physics didactic concepts for experimentation, modern physics teaching also requires mathematical didactic knowledge to deal with the technical problems of mathematics (Schwarz, 2016). Consequently, the repertoire of future teachers will become richer by incorporating the didactics of neighboring subjects. Hence this project aims to make a meaningful and lasting impact through teacher training, combining classroom teaching with practical instructions. The objective is the development of a competence-oriented curriculum for teacher training in Hanoi.

The previously mentioned projects at the University of Siegen have demonstrated that interdisciplinary teaching in teacher education provides a deeper insight into the didactics (Witzke, 2015). The combination of didactical theory and teaching practice is particularly important to our approach.

3.2. Inter-TeTra

Consequently, the DAAD (German Academic Exchange Service) endorses the Inter-TeTra-project (the name of the project is a short form for Interdisciplinary Teacher Training), a subject-related partnership established between the University of Siegen (Germany) and Hanoi National University of Education (HNUE, Vietnam). The primary goals of this project are the design of a permanent module for the subject’s mathematics and physics at HNUE and the implementation of an interdisciplinary course in HNUE’s master’s program and of an in-service teacher training. One of the distinguishing features of the courses is the view beyond the subject boundaries of mathematics and physics.

Figure 4. Concept of the seminar “In ForM PLUS”, as it is currently taught at the University of Siegen. The new international project Inter-TeTra is based on the structure of this seminar. (source: Krause & Holten, 2018)

Inter-TeTra - Research and university teaching

Figure 5. Basic structure of the “Inter-TeTra” project
Concept of the Courses in the Inter-TeTra-Project

The Inter-TeTra project takes four years. In the first year (2018) the researchers from Vietnam have joined the referring projects in Siegen, the FiMaPDi and InForM PLUS projects (Krause & Holten, 2018), and both sides discussed the theoretical framework of the project. The courses for HNUE will be designed in the year 2019, take place in Hanoi in 2020, and will be revised and repeated in 2021. The guiding idea is the implementation of an interdisciplinary course for Master students in the teacher training curriculum at HNUE and the offering of an interdisciplinary course for in-service teachers with the subjects’ mathematics and physics. These courses will be composed by a theoretical and a practical part. The Master’s course will consist of two components, a lecture with a theoretical focus and a seminar with a practical focus.

Theoretical Part

The aim of the courses is to enable students to compare the didactical theories of their own discipline, which they have come to know during their studies, with the didactical theories of the other subject. In our case, the comparison, therefore, takes place with either mathematics or physics didactics, respectively. Since only a limited number of sessions are available for the theoretical part, only a selection of topics can be found that is relevant for both subjects. One research desideratum, that the Inter-TeTra project focuses on, is to identify topics which are relevant for mathematics and physics education (see section 3.2).

Practical Part

In addition to the theoretical sections the courses mentioned and planned in this project will also include lessons at schools. The fact that the didactics of a neighboring subject can be relevant to one’s own subject should be clarified by the conception, implementation, and reflection of lessons that try to combine school mathematics and physics in a meaningful way. For this purpose, the interdisciplinary comparison of theories on learning and teaching mathematics and physics in schools will be used to develop research questions in the seminar. Those questions will be examined in the course of the lesson designs developed in the seminar and tested at the cooperation school. These lessons are recorded on video and compared with the theory previously discussed. This combination of theoretical lessons and review has been established in North Rhine-Westphalia (one of Germany’s federal states) during the practical semester in teacher training (Hoffart & Helmerich, 2016). However, evaluation criteria do not refer primarily to how the lessons themselves succeeded, but to how the teaching process can be analyzed and classified on the basis of the theoretical sessions. At this stage of the seminar, students should be able to evaluate and justify didactic decisions based on theory.

Accompanying Research and Evaluation

Within the first project phase, the explication of the theoretical basis is carried out. This means that the intersection of the didactic literature of the participating subjects is determined. Within the first step, these comparisons are based on the German-speaking countries, using the method of structured content analysis. In order to avoid distortions due to selection effects and different priorities in different regions, the next step is to add international perspectives to the determination of the intersection.

On this basis, the effects of interdisciplinary teacher training are to be evaluated. In the further course of the overall project, the research perspective will therefore be expanded to include comparative quantitative and qualitative elements. This accompanying research refers to the implementation of the Master’s course in Vietnam and will start in 2020.

The literature-based comparison is relying on current manuals and general textbooks of both subject didactics. Furthermore, contributions in conference proceedings (GDM and DPG conferences in Germany) from the years 2014-2018 will be taken into account in order to reflect the latest developments. The preliminary results of the comparison, which are to be extended to include the international perspective, are briefly presented below.

Even if this research is still in progress, an exemplary selection of topics, which are suitable for an exchange between mathematics and physics education, can be listed:

- Beliefs on Mathematics / Physics
- Didactical Principles / Principles of Learning Theory
- Beliefs / Scientific Misconception
- Subject Matter Didactics
- Models / Modeling / Applications
- Concept Formation
- Arguing and Proving
• Experiments
• Exercises
• Interdisciplinarity / Combining Subject Didactics

A more particular description of the underlying methodology and a detailed overview of the conceptual content cannot be provided within the scope of this article. However, a corresponding article will appear soon.

Three subject areas, in particular, play an important role here since they are equally taken into account by both subject didactics. These are in detail the areas 1) Nature of Science respectively Beliefs of Mathematics, 2) Modeling, 3) Preconceptions. In the following we will briefly explain what can be understood by these terms.

Nature of Science vs. Beliefs of Mathematics: What is physics? What role does the experiment play in physics? To what extent does a physical theory depict reality? Because questions of this kind are crucial for teaching-learning processes, the didactics of physics has been dealing with them for some time under the heading “nature of sciences” (Hötticke & Rieß, 2007). Likewise, also the mathematics didactics research on the different views on mathematics (e.g., Witzke & Spieß, 2016; or Grigutsch et. al, 1998) because the individual conceptions determine our concrete activities in science. What similarities can be identified between perceptual research in mathematics didactics and Nature of Science research in physics didactics? What are the differences?

Modeling: In physics, models (such as atomic models) are an integral part of the theory canon. Accordingly, the physics education has to clarify how to deal with models in the teaching-learning process. It is not so common to stress that models should not be viewed as appeared from nowhere, but rather emphasize the process of creating models. In mathematics didactics modeling has been discussed for many years. Several models for modeling - so-called modeling cycles have been developed. So it seems that physics didactics focus on the product while mathematics didactics is more interested in the process of modeling. It is obvious that both sides can learn from each other in this matter, even if it is more laborious than it seems (Neumann et al., 2011).

Preconceptions: In physics didactics, preconceptions are associated with different physical contents. They are often negatively connoted as misconceptions. In mathematics education one rarely speaks about misconceptions, trying to highlight positive pre-theories among learners. The term “Grundvorstellung” (“basic concepts”, vom Hofe, 1992) is certainly prominent in this context in Germany. At the same time, mathematics educators have developed more general theories on context-related learning, which can also be applied to other subjects. For example, the approach of Heinrich Bauersfeld to “Subjektive Erfahrungsbereiche” (“subjective experience areas”) should be mentioned (Bauersfeld, 1983). Krause has sketched the transfer of this theory to physics and discussed the question how, on the other hand, mathematical didactics can be fertilized by approaches of physics didactics (Krause, 2015).

4. CONCLUSION

The project is based on existing concepts of the University of Siegen. A common element of these concepts and our new project is the fact that they all take place much earlier in teacher training than comparable ideas. The focus is not only on the practical design of teaching content but on the combination of both subject didactics. The aim is to enable teachers to better diagnose and control learning processes, including the development and evaluation of teaching materials.

The accompanying research should ensure that a common, broad basis of subject didactic topics is taken into account without having to fear distortions due to the respective national teacher training. The performance of the courses will be evaluated in order to assess the effectiveness of interdisciplinary teaching in the subjects’ mathematics and physics during the training of teachers.

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