Relevant Content for a Scientific Collaboration in Mathematics and Physics Education Research - A Comparative Content Analysis of Handbooks and Conference Proceedings in Germany and Vietnam

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ABSTRACT

This article presents a possible framework for the cooperation of mathematics and physics education research domains. Moreover, the potential topics for such a scientific collaboration are explained by means of a structuring qualitative content analysis of current handbooks and conference proceedings in Germany and Vietnam. These topics can form a basis for further projects on the connection of subject-related didactics. One of these projects is an interdisciplinary course in teacher training at the Hanoi National University of Education (HNUE) as part of the Inter TeTra project between the HNUE and the University of Siegen.

Keywords: interdisciplinarity, international comparative study, qualitative content analysis, relationship between mathematics and physics, STEM education, teacher training

INTRODUCTION

Mathematics and physics educators from the University of Siegen and the Hanoi National University of Education are collaborating within the Inter TeTra project. The objective of this project is the systematical combination, application and reflection of the involved disciplines (Kraus et al., 2018; Krause et al., 2019). An essential intermediate goal of this cooperation is the identification of content intersections between the involved didactics. The results of this analysis are presented in this article.

The second section shows a literature review on interdisciplinary collaboration of education researchers in this field. It describes why the cooperation of German and Vietnamese educators as well as mathematics and physics educators is particularly suitable. The research questions are presented in the third section and the fourth section describes the research process and methodology. The research result is described in section "Results of the study". Section "Explication of possible topics for a science collaboration of mathematics and physics didactics" deals with the interpretation of the results by a short description of the respective comparison points of both disciplines.

Contribution of this paper to the literature

- A structured comparison of conference contributions and common handbooks of mathematics and physics education research allows us to identify possible common research topics.
- On the basis of a survey of experts, a selection is made of such topics that have a special potential for deeper discussion in an interdisciplinary course in the teacher training program, in which the participants learn to recognize and use the synergies of both subjects for a contemporary interdisciplinary teaching.
- We carry out a comparison between countries that have made varying degrees of progress in implementing competence-oriented teaching; current trends in research in the participating countries are compared.

ABOUT THE POTENTIAL OF INTERDISCIPLINARY COLLABORATION OF EDUCATION RESEARCHERS

Collaboration of German and Vietnamese Teacher Educators in the Context of the Educational Reforms in Vietnam

In international comparative studies, Vietnam usually achieves very satisfactory results (in the last PISA study, Vietnam achieved better rankings in the disciplines Mathematics and Science than, for example, the USA and the UK), but the educational provision still shows weaknesses in particular in the tertiary sector (Tran, 2018a). In 2006, Vietnam adopted an agenda for higher education reform that promised significant improvements in higher education by 2020 (Hayden & Thiep, 2006). The education system was to evolve from a more Soviet to a Western style (Whitney et al., 2018). Therefore, the globalization of higher education is one of the fundamental initiatives (Tran, 2018b).

In the area of teacher training, the reforms are primarily aimed at establishing competence-oriented curricula (Communist Party, 2013). This means that teachers are asked to design lessons in such a way that students can apply the acquired skills and abilities in various situations in a problem-solving manner. Therefore, interdisciplinarity is a logical consequence of the demand for competence-oriented teaching and learning, since authentic contextualization of learning content usually goes beyond the boundaries of subjects. Germany has two decades of experiences with these types of reforms. The adjustments of the curricula since the mediocre results of German students in the TIMSS and PISA studies show the opportunities and challenges such reforms can present (KMK, 2004) and the importance of teacher training for the success of school reforms (Hattie & Beywl, 2013). Therefore, the cooperation between German and Vietnamese educators offers the opportunity to avoid well-known problems in implementing such reforms.

Teaching and Learning in STEM – With a Focus on Mathematics and Physics

Competence-oriented Mathematics education should enable students to understand phenomena in nature and society (Sevinc & Lesh, 2018). Similarly, the description of phenomena of reality is a central goal of physics education. However, these phenomena are not divided into single subjects. Of course, it makes sense to structure knowledge in subjects and to adopt problems with subject-specific methods for many purposes. Nevertheless, interdisciplinary approaches can provide meaningful insights – especially in STEM. Since the establishment of competence orientation, the didactic potential of interdisciplinary teaching and learning in schools has actually been emphasized more strongly. Different approaches have been developed (Doig et al., 2019). In addition, interdisciplinary activities replace the divided teaching of subjects (e.g. Project-based learning). It seems useful to teach the single subjects in an interdisciplinary way by establishing links to related subjects. For example, mathematics is related to numerous applications of STEM-subjects (science, technology, engineering, mathematics) (Trần & Kraus, 2017), but also to the social sciences (politics, geography, etc.) (Trần, 2013) and the artistic field (sports, music, art etc.). Such applications can be integrated into the mathematics lessons in a meaningful way (Trần & Krause, 2017). The potential of interdisciplinary teaching and learning has been discussed extensively in the context of STEM-education (English, 2017; Kelley & Knowles, 2016; La Force, 2016; Michelsen, 1998). Regardless of the increasing demands of interdisciplinary teaching within the subjects, science, technology, engineering, and mathematics (STEM), there is no agreement on a definition of STEM (Baker & Galanti, 2017; Fullan, 2007). According to some authors, STEM can already be considered if only two disciplines from this field are integrated (Ríordáin, Johnston, & Walshe, 2016; Treacy & O'Donoghue, 2014). The cooperation between mathematics and physics didactics seems to be particularly useful, because mathematics and physics also exhibit numerous synergies as academic disciplines. In the historical genesis, mathematics and physics have been beneficial in many ways (Galili, 2018; Krause, 2018). In fact, mathematics didactics has a high relevance in the research of teaching and learning processes in physics (Krause, 2017b). For example, the high presence of mathematical notations and

techniques in quantitative physics makes mathematics didactic aspects on dealing with formulas very interesting for physics didactics.

In mathematics lessons, physics is very present, too. It provides authentic contexts in many areas of school mathematics. Students in mathematics lessons should learn how mathematics can be used to perceive and understand natural phenomena (see e. g. Carrejo & Marshall, 2007). However, mathematics teachers are often overwhelmed with physical contexts because they lack both the contentual and the subject-specific didactic knowledge (Krause, 2017a).

The Inter TeTra Project as an Interdisciplinarity Intervention in University Teacher Training

In Vietnam, educational researchers currently work on approaches for establishing interdisciplinary lessons in Vietnam (Nguyen & Thanh, 2014 or Nguyen, 2015). Studies in Vietnam show that interdisciplinary teaching is aimed to motivate students, put them in authentic activities, develop their integrated skills and their competencies to solve real-world problems (Đỗ et al., 2016; Nguyen, 2016). Processes of designing and organizing interdisciplinary teaching are also studied (Đỗ et al., 2016; Nguyen et al., 2018, 2019). The new Vietnamese General Curriculum, adopted in 2018, contains a new change in the lower secondary level: the three subjects, Physics, Chemistry, and Biology are integrated into a new subject named "Natural Science". Together with this integration, the curriculum emphasizes that the goal of the new subject "Natural Science" is "to help students gradually form and develop their natural science competencies through observations and experiential learning, synthesize integrated knowledge and skills to solve problems in real life, and perform STEM education together with other subjects such as Mathematics, Technology, Informatics…". (MOET, 2018, p. 20). STEM education is also mentioned in the objectives of teaching mathematics: "Mathematics education establishes connections between mathematical ideas, between mathematics and real life, between mathematics and other school subjects and other educational activities, especially the connections between mathematics and the subjects Science, Natural Science, Physics, Chemistry, Biology, Technology and Informatics to perform STEM education" (MOET, 2018, p. 17).

Although recognizing the importance of interdisciplinary teaching, the Vietnam Ministry of Education and Training still have difficulties in performing it. The school curriculum was innovated but the pre-service teachers' curriculum still has not changed in the pedagogical universities. This contradiction leads to the problem that when pre-service teachers graduate and become teachers, they do not know how to integrate school subjects in the teaching process. The survey in the project "Teaching mathematics at the high school level in an integrated way through interdisciplinary projects" shows that high school mathematics teachers understand and are aware of the necessity of interdisciplinary teaching but they have difficulties in applying it, because of the limited teaching time, the lack of instructive documents, and the lack of the (pedagogical) content knowledge of other subjects (Nguyen & Nguyen, 2019).

In Germany, the advantages of interdisciplinary teaching and learning in schools have been emphasized extensively in the form of problem-based and cross-disciplinary teaching which is organized in projects (Labudde, 2014 or Moegling, 2010). Numerous approaches have been developed in order to achieve the greatest success of learning (Caviola, 2012 or also Labudde, 2008). However, interdisciplinary collaborations also reveal different challenges. For instance, combination of different methods of the participating subjects and the identification of common research subjects are significant (Defila & Di Giulio, 2002, 24). The contrast of a non-integrated teacher training and the requirements of interdisciplinary teaching (Bröll & Friedrich, 2012) is repeatedly mentioned by teachers in German schools as an argument against interdisciplinary teaching (Jürgensen, 2012; Rehm et al., 2008). The importance of adequate preparation is also demonstrated in several studies (Brown & Bogiages, 2017; Cormas, 2017). In order to prepare teachers adequately for this variety of challenges, we believe that early intervention is necessary in the first phase of teacher training. Nevertheless, the teacher training in Germany and Vietnam is predominantly still organized in a discipline-oriented manner. In contrast, the aim should be to implement holistic concepts for integrative teacher education. Thus, interdisciplinary teaching and learning in schools are more than stringing together elements of knowledge from different disciplines (Wellensiek, 2002, 80).

RESEARCH QUESTIONS

The potential synergies between mathematics and physics didactics formulated in Chapter 2 are systematically highlighted by means of a structuring analysis of handbooks for both subject-related didactics and of conference proceedings. The research questions are as follows:

1) Which of the educational research subject areas within mathematics and physics currently being discussed in Germany and Vietnam are relevant for both subjects?
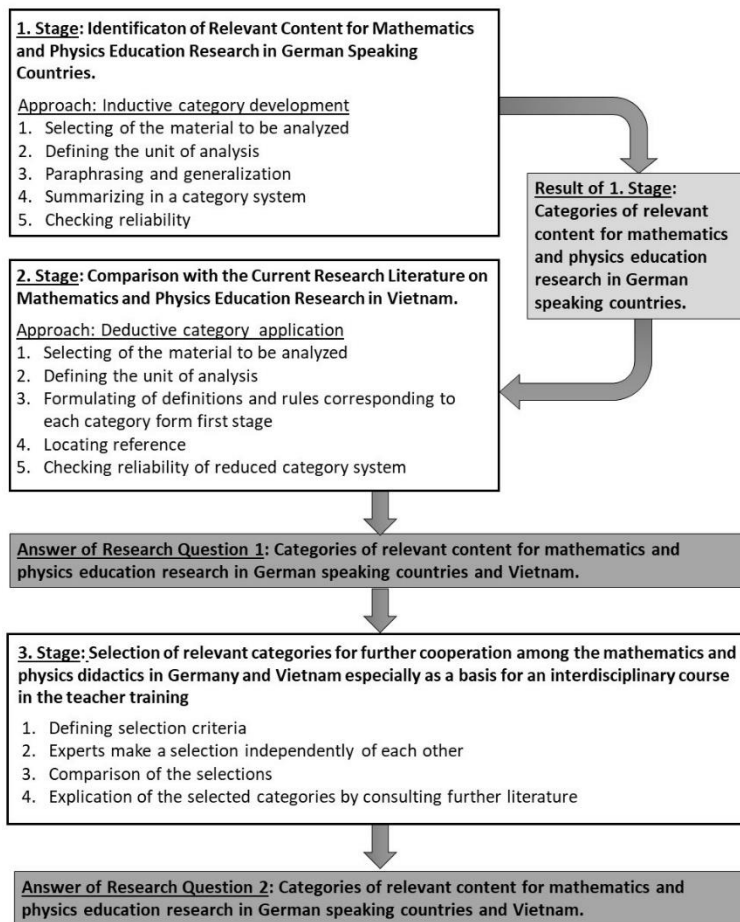
1. Stage: Identificaton of Relevant Content for Mathematics and Physics Education Research in German Speaking Countries.

Approach: Inductive category development
1. Selecting of the material to be analyzed
2. Defining the unit of analysis
3. Paraphrasing and generalization
4. Summarizing in a category system
5. Checking reliability

Result of 1. Stage: Categories of relevant content for mathematics and physics education research in German speaking countries.

2. Stage: Comparison with the Current Research Literature on Mathematics and Physics Education Research in Vietnam.

Approach: Deductive category application
1. Selecting of the material to be analyzed
2. Defining the unit of analysis
3. Formulating of definitions and rules corresponding to each category form first stage
4. Locating reference
5. Checking reliability of reduced category system

Answer of Research Question 1: Categories of relevant content for mathematics and physics education research in German speaking countries and Vietnam.

3. Stage: Selection of relevant categories for further cooperation among the mathematics and physics didactics in Germany and Vietnam especially as a basis for an interdisciplinary course in the teacher training

1. Defining selection criteria
2. Experts make a selection independently of each other
3. Comparison of the selections
4. Explication of the selected categories by consulting further literature

Answer of Research Question 2: Categories of relevant content for mathematics and physics education research in German speaking countries and Vietnam.

Figure 1. Graphical representation of the general research process sequence

2) Which of the contents found are particularly valuable as a basis for further cooperation among the mathematics and physics didactics in Germany and Vietnam especially as a basis for an interdisciplinary course in the teacher training?

METHODOLOGY

Basis for Selecting Methods and Research Process

In order to answer the first research question, the content needs to be qualitatively analyzed. The method chosen in this study is based on the theory of qualitative content analysis according to Mayring (2000). Qualitative content analysis is used in two different ways in this study - inductive development of categories as well as deductive application of categories.

Since so far no study has systematically identified common topics in mathematics and physics education research in German-speaking countries as well as in Vietnam, it is necessary first to use the approach of inductive category development. If the German and Vietnamese literature were analyzed parallel as inductive category development approach, we would have results of two independent categories. Since this is a qualitative analysis, the results depend subjectively on the researcher. Therefore, the structure of the system of categories can be very different and hard to compare. Hence, the research process is arranged in three successive stages. In the first stage, the contents are identified, which are relevant for both mathematics and physics education research in German-speaking countries. This analysis is carried out according to the inductive development of categories. In the second stage, the results of the first stage are compared with the current literature on mathematics and physics education research in Vietnam. The analysis in this stage is carried out according to the deductive application of categories (cf. **Figure 1**). As a result of these two stages, the first research question can be presented in the form of a list of categories relevant to the didactics of both subjects and countries.

In the third stage of the research process, the second research question is answered. Therefore, criteria are defined for the selection of particularly relevant topics. Further literature was consulted to explicate the possible topics envisaged in the second research question. The content intersection identified in this way can form the basis for further cooperative research and teaching projects, such as the development of integrated teacher training at universities described above.

Description of Methods

Based on the first research question, the relevant literature is analyzed as inductive qualitative content in five steps. The result of this analysis are the German categories according to the approach: Inductive category development for qualitative content analysis from Mayring (2000). The first step is the selection of the handbooks and conference proceeding to be analyzed. The criterion for the literature selection is, the popularity of being used at German universities. In the second step, the material is described in detail, and the single units of analysis are defined. These are the contributions in the handbooks and conference proceedings. Therefore, the content of a single contribution forms the unit of analysis, which is examined for the relationship between the disciplines of mathematics and physics didactics. In the third step, the relevant parts of the text are summarized in a form limited to the content (paraphrasing). The paraphrases are generalized on a defined level of abstraction. The abstraction level is the topic of the contributions in the concrete case, whereas the generalization already followed from an interdisciplinary perspective (mathematics and physics didactics). In the fourth step, the statements are summarized in a system of categories. For this purpose, the inductively obtained subcategories are arranged by forming seven main categories. The category system was checked on the basis of the literature, in the last step of the analysis. These results of the German analysis have already been published (Dilling et al., 2019).

After creating the German categories, the relevant Vietnamese literature is analyzed according to the five-step deductive category application approach according to Mayring (2000) also taking into account the relationship between mathematics and physics. The first and the second step are done similar to the first two steps of the first research stage on the basis of the Vietnamese literature. The deductively developed system of categories based on the first research stage is presented in the third step and is applied to the Vietnamese literature in the fourth step by indicating definitions, coding rules and examples within the Vietnamese literature. This part of the result is presented in section "Explication of possible topics for a science collaboration of mathematics and physics didactics". In the last step, each category, which cannot be identified in the Vietnamese literature is excluded to form a new system of categories as a premise for research collaborating didactics of both subjects and countries, and to answer the first research question. To answer the second research question, each category with corresponding content is analyzed on the perspective of science collaboration and designing topics related to form the interdisciplinary course at the HNUE. For this purpose, a selection of particularly relevant contents for scientific cooperation in mathematics and physics didactics is independently made by proven experts in mathematics and physics didactics. These experts should make this selection independently of each other and according to the following qualification criteria:

Q1 Subject-specific relevance (topics that are analogously relevant in all subjects, e.g. the contribution to general education should not be discussed in the projected)

Q2 Relevance for the mathematics and physics teacher training program

The comparison of the selection of the respective experts led to the list of topics presented in "Selection of the Subject Specific Topics" as answers to the second research question.

RESULTS OF THE STUDY

Handbooks and Conference Proceedings in Germany

In order to reveal relevant subject areas for exchange between mathematics and physics didactics, the contents of nine basic mathematics and physics didactics handbooks as well as the contributions of the major conferences, the Gesellschaft für Didaktik der Mathematik (Society for Mathematics Education) and the Deutsche Physikalische Gesellschaft (German Physical Society), from 2014 to 2018, are compared. Contributions for conferences concerning other natural sciences (e.g. GDCP conference, MNU congress) are not included in the analysis in order to focus specifically on the connections between mathematics and physics education research. The analyzed conference proceedings represent an overview of the current research interests of mathematics and physics didactics. The inclusion of newer and older handbooks also makes it possible to take traditional research interests of the German-speaking research communities into account. Together, they form the analysis corpus of this study. The handbooks and proceedings, which are used for the analysis, are listed in **Table 1**.

Table 1. Overview of the analyzed handbooks and conference proceedings from the German-speaking countries.

Mathematics	Physics
Handbooks	Handbooks
Bruder et al. (2015)	Kircher et al. (2015)
Krauthausen (2008)	Kircher et al. (2002)
Leuders (2003)	Mikelskis (2006)
Leuders (2015)	Wiesner et al. (2011)
Reiss & Hammer (2013)	
Zech (2002)	
Proceedings	Proceedings
Beiträge zum Mathematik unterricht 2014-2017 as well as the program of presentations of the GDM 2018.	PhyDid B 2014-2017 and the program of presentations of the DPG Conference for Physics Didactics 2018.

Table 2. German categories

Number	Description
C1	**Mathematics (didactics) and Physics (didactics) as scientific disciplines**
C1.1	Relevance of mathematics/physics
C1.2	Mathematics/physics didactics as a scientific discipline
C1.3	Beliefs about mathematics/physics
C1.4	History of mathematics/physics (in class)
C2	**Theories of didactics**
C2.1	Didactic principles / theoretical principles of learning
C2.2	Students' ideas / pre-concepts / basic ideas / ...
C2.3	Subject Matter Didactics
C3	**Objectives and competencies in mathematics and physics teaching**
C3.1	Objectives and competencies
C3.2	Model / Modeling / Applications
C3.3	Definition/concept formation
C3.4	Problem-solving
C3.5	Arguing and proving
C3.6	Experimenting
C3.7	Communication / Language
C4	**Teacher training**
C4.1	Teacher training/professionalization of teachers/competencies of teachers
C4.2	Student laboratories / Teaching and learning laboratories
C4.3	Transition from school to university/commencement of studies
C5	**Teaching practice and pedagogical topics**
C5.1	Planning, analysis, and organization of lessons
C5.2	Teaching methods
C5.3	Performance assessment and diagnostics
C5.4	Media
C5.5	Differentiation / heterogeneity / inclusion
C6	**Tasks**
C7	**Subject connection / subject didactics connection**

The analysis of the handbooks and conference proceedings results in a total of 24 categories representing related topics of mathematics and physics didactics. The developed categories can be grouped into seven main categories with partial splitting into several subcategories and ultimately enable the identification of 24 subject areas, that are comparable between the two didactics. A corresponding list of the categories is shown in **Table 2**. Additional anchor examples are given in **Table 4** in the **Appendix**.

Comparison with the Vietnamese Literature

Selection of literature

There are two types of literature, which are selected for this analysis: handbooks and conference proceedings. The criterion for the selection of handbooks is their dissemination at Vietnamese universities of education. The criteria for selecting those conference proceedings are the proceedings from prestigious conferences in the field of

Table 3. Overview of the analyzed handbooks and conference proceedings from Vietnam

Mathematics	Physics
Handbooks	Handbooks
Nguyen(2017)	Đào (2003)
Nguyen et. al (1994)	Đỗ (2006)
Bui (2011)	Đỗ (2012)
Bui (2017)	Đỗ (2014)
Dao & Tran (2010)	Đỗ et al. (2016)
	Đỗ et al. (2019)
Proceedings	Lê et al. (2004)
The national conference of research on mathematics education	Nguyễn &Nguyễn (2001)
in the orientation of developing learners' competencies for the	Nguyễn et al. (2002)
period 2014-2020 (2014).	Phạm (2001)
The conference of developing professional competencies for	Phạm (2007)
Vietnamese school mathematics teachers (2015).	Proceedings
The international conference in mathematics education: An	Proceeding of Vietnam national conference for physics
integrated approach in mathematics education and teacher	teaching, from 2010 to 2018
training (2018).	

mathematics and physics didactics from 2010 to present. Accordingly, the handbooks and proceedings listed in **Table 3** are chosen for the analysis.

The reduced category system

For each German category analyzed in the previous stage, we choose which category is valid in the Vietnamese literature. From there on, the reduced category system is formed. In comparison with the Germany category system, there is no presence of the main categories C6 and C7. In addition, the categories C4.2 and C4.3 cannot be found parallel to their reference in both the mathematics and physics didactics in Vietnamese literature. The detail result is shown in **Table 4** in the **Appendix**.

Selection of the Subject Specific Topics

The categories, which are obtained from the comparative analysis, represent exactly those subject areas, which are discussed in both subject didactics nowadays and are shaped by related contents. They describe both traditional (e.g. C1.1) and new (e.g. C3) knowledge interests of the two subject didactics. The categories differ in their didactic potential with regard to a comparison in the sense of a subject-didactic-connecting approach. i.e. regarding the integrated teacher training described at the beginning of an interdisciplinary scientific exchange with other objectives, the categories presented here have different relevance.

In order to filter out subject-specific topics that are particularly relevant for scientific cooperation from the list of discussed topics in mathematics and physics didactics in Germany and Vietnam, experts from both subjects and from both countries are asked to make an appropriate selection independently of each other. The comparison of this selection of experts led to the deletion of the following topics:

- C2.1 General didactic principals
- C2.3 Subject matter didactics
- C3.7 Communication and language
- C6 Tasks in class

Hence, the following seven topics have proved particularly promising for cooperation between mathematics and physics educational research:

- C1.3 Beliefs about mathematics and physics
- C2.2 Preconceptions
- C3.2 Models and Modeling
- C3.3 Concept formation
- C3.4 Problem-Solving
- C3.5 Arguing and Proofing
- C3.6 Experimentation

EXPLICATION OF POSSIBLE TOPICS FOR A SCIENCE COLLABORATION OF MATHEMATICS AND PHYSICS DIDACTICS

Beliefs about Mathematics and Physics

Physics education in Germany (GP): The term Nature of Science (NoS for short) has long been used in physics didactics to describe the philosophical background of the natural sciences. The methodology of physics within the framework of theory-building processes is thereby explained as a central teaching subject. The experiment functions both as a medium and learning object in physics teaching and as a decisive explanatory instance and a link to reality in scientific methodology (Kircher, 2015). The ideas of students of NoS are also regularly discussed in the didactics of the subject (Höttecke & Rieß, 2007).

Mathematics education in Germany (GM): In mathematics didactics, subject-specific views on mathematics are increasingly being investigated in open questionnaire studies (Rott et al., 2015). Grigutsch et al. (1998) were able to identify four factors in the attitude of mathematics teachers towards mathematics in a closed questionnaire format. ´This format still serves as the basis for studies (Witzke & Spies, 2016). These are the formal aspects, in which mathematics is attributed rigor and exactness at different levels: the application aspect, which illuminates every day and social relevance, the process aspect, according to which mathematics is constructively understood as a process, and the schema aspect, which regards the algorithms and schemata of mathematics as tools.

Physics education in Vietnam (VP): NoS is also presented by Phạm (2007). In addition, Nguyễn & Nguyễn (2001) illustrate NoS in the history of physics. Experimental methods and modelling methods are considered basic methods for natural awareness, and considered as subjects to be learned by students (Nguyen et al. 2002).

Mathematics education in Vietnam (VM): In mathematics education, beliefs about mathematic is mentioned by Nguyen (2017) through the properties of the subject mathematics: mathematics is highly abstract, popularly applicable, logical and experimental. According to Nguyen, the abstraction in mathematics is expressed in different ways. In other words, the highly abstract property makes mathematics be popularly applicable, that means mathematics can be applied in various fields and become a useful tool of these fields. Nguyen also emphasizes the logic and experimental properties of mathematics and concludes that the unification between deduction and prediction of mathematics is a property of mathematical thinking. We stress that both aspects of the teaching process be included to ensure the comprehensive goal of education (Nguyen, 2017).

A comparison of the research on the understanding of mathematics and physics didactics can provide deeper insights into the backgrounds and methods of one subject and the connection with the other. The scientific philosophy of the involved subjects has to be known to enable interdisciplinary learning.

Preconceptions

Ideas of different groups of persons concerning the contents of mathematics and physics are the more frequent subject of research in both didactics.

GP: In this context, physics didactics often speaks of everyday idea of physical phenomena that students should acquire outside the classroom. They are deeply rooted and often not compatible with scientific theory. This is the reason why the negatively connoted word "misconceptions" is often used in this context. The lessons should respond to the students' ideas and bring out a change of the concept. This can be done either by connecting and reinterpreting the ideas or by cognitive conflict and subsequent learning of the new concept (Duit, 2015).

GM: In mathematics didactics, students' ideas are examined in different contexts. According to vom Hofe (1992), basic ideas (Ger.: "Grundvorstellungen") can, in particular, be seen as a prescriptive description of ideas. On the basis of the mathematical content, possible ideas are developed which the teaching is intended to convey in this field. Examples in the field of analysis can be found in Greefrath et al. (2016). In contrast, there are many descriptive perspectives on the concept of imagination. These include, among others, the subjective fields of experience according to Bauersfeld (1983) as well as different approaches of the field of beliefs (e.g. Pehkonen & Pietilä, 2004; Schoenfeld, 1998).

VP: Đỗ (2014) does not only present the psychological basis of preconception, but also makes suggestions to use preconception in teaching to have beneficial learning results. Furthermore, practical research on misconception is also explored by Hà (2016).

VM: In mathematics didactics, preconceptions are almost not mentioned. Only misconceptions are considered. Nguyen (2017) mentions "obstacles" as one kind of students' misconception. He differentiates "avoidable obstacles" and "unavoidable obstacles" and proposes methods to deal with each kind of obstacles in the teaching process (Nguyen, 2017). Other researcher focus on identifying common mistakes or misconceptions that students do by studying specific mathematical content such as quadratic equation (Ho, 2018) or 3D-geometry (Bui, 2011).

Krause (2015) examines the comparison between mathematics and physics didactics and subjective learning preconditions in detail. The authors' impression is that cognitive-psychological aspects of subjective learning prerequisites have long been discussed in mathematics (Bauersfeld, 1983, among others). These are usually not specific for mathematics. Hence, these approaches could also be applied in physics didactics. Scientific exchange in this area seems very beneficial from the authors' point of view.

Models and Modelling

GP: Models are important components of the process of acquiring knowledge in physics and physics teaching. For this reason, physics didactics deals with the concept of models for a long time. Of particular importance is the relationship between model and object as well as the properties and functions of models (Kircher, 2015). The students should be actively integrated into the developmental process of models and modelling. Hence, the student should be aware of the fact that models are not regarded as something naturally given (Mikelskis-Seifert & Kasper, 2011). Important for physics didactics are also considerations about what teachers should know about models (Oh & Oh, 2016).

GM: In mathematical didactics, the interest is less in the model as an already finished product, but rather in the process of modelling. The model is supposed to be a link between mathematics and reality (Kaiser et al, 2015). In this course, different modelling cycles were developed, which represent models for the process of modeling. One of the best-known modelling cycles is the model by Blum and Leiß (2005).

VP: The analysis of the development of the concept of models in physics and the suggestions of the levels of modelling used in teaching are presented by Nguyễn and Nguyễn (2001). Nguyễn et al. (2002) detail the analysis of the characteristics of model types and introduce the concept of modeling methods consisting of a teaching process that uses modelling with four phases. Modelling in physics is also considered in relation to inductivism and with experimental methods (Phạm, 2007).

VM: In mathematics didactics, the mathematical modelling competency is considered as one of the crucial competencies (Bui & Chu, 2014). Bui and Chu (2014) propose some real life topics for the high school mathematical contest in modeling, which can help students develop modelling capacities. Ho (2018) uses the model of Blum & Leiss (2005) to describe the process to solve realistic problems. The result of her questionnaire for grade 10 students shows that students have difficulties in mathematizing "real situation" to build a beneficial mathematical model, and in interpreting "mathematical solution" to "realistic solutions" for realistic problems. Thinh (2014) proposes methods of using models (which is called the method of symbolization) to teach analysis concepts efficiently. Tran et al. (2014) and Pham et al. (2018b) introduce methods of using mathematical software in teaching to create models such as graphs, figures, patterns or simulate objects, real world scenarios. This software-based modelling method can help to motivate students, diagnose their mathematical conceptions, visualize the problem situations, and overcome algebraic barriers (Tran et al., 2014; Pham et al., 2018b).

Now, if physics didactics has expertise on the subject of "models" and mathematics didactics has many years of research experience in modeling, an exchange of scientific knowledge on these themes seems obvious and profitable for both sides. The opportunities and challenges of bringing together mathematical modelling and modeling in physics lessons are shown by Neumann et al. (2011).

Concept Formation

GP & GM: The terms are central elements of mathematics expertise and mathematics teaching. In mathematics education research, the learning of terms is generally understood as a constructive process, in which students develop an increasingly precise understanding of a term (Vollrath, 1984). A distinction is made between different types of conceptualization, including exemplary conceptualization, conceptualization through abstraction, specification from a generic term, and conceptualization based on actions (Weigand, 2015).

The supposedly greatest difference in the formation of concepts in mathematics and physics seems to be in the fact that concepts in mathematics are deductive determinations and in physics they are inductively obtained by classifying and systematizing empirical observations. This view is also supported by numerous older physics didactic works (e.g. Klinger, 1989). More recent studies discuss critically the purely inductive character of physical concepts (cf. Krause, 2017c). Although, terms in physics are stimulated by empirical phenomena, their epistemological character is more related to terms in mathematics: they are creations of the mind that are built into the deductively ordered mental building of science.

In mathematics didactics, abduction is discussed in connection with the topic of "concept formation" (Meyer & Voigt, 2008 or also Söhling, 2015). For example, the didactic theory of concept learning is described and empirically researched on the basis of abduction (Meyer, 2012).

VP: Nguyễn et al. (2002) and Đỗ (2012) introduce the concept of knowledge and concepts of natural cognitive methods. Each of these concepts is further divided into sub-concepts – corresponding to the steps to form them in physics teaching. Phạm (2007) provides a model for formation the concept. This concept consists of field theory and real object field, and is accompanied by a concept formation process in teaching with four recommended stages.

VM: In mathematics didactics, it is important that we should form steadily a system of concepts for students because concepts are the fundamental basis of the mathematical knowledge. Nguyen (2017) mentions to three processes to approach a concept which are: the deductive process, the inductive process and the constructive process. He also shows advantages and limitations of each process. Some other research mentions specific methods to help students in concept formation, such as software-based modelling method (Pham et al., 2018b; Tran et al., 2014), using symbolized method (Thinh, 2014), construct learning tasks (Phan, 2015), applying constructivism theory (Bui, 2017) or using intuiting approach (Vo, 2018).

Abduction is also discussed in physics didactic research (cf. McComas, 2002), but it would be interesting to discuss it against the background of epistemological parallels to mathematics.

Problem-solving

Problem-solving is a fundamental competence of mathematics teaching and a classical field of research in mathematics education research. A lot of different conditions influence the problem-solving process, including cognitions (domain knowledge and heuristics), metacognition (knowledge about mathematical thinking, control processes) and the basic attitude. Mathematics education research examines, in particular, the course of problem-solving processes and the possibilities of acquiring problem-solving competence (Heinrich et al., 2015). Important representatives are Pólya (1949) and Schoenfeld (1985).

GP: In physics didactics, attempts are made to work out general heurisms as well as physics-specific solutions to problems. Among others, the knowledge-centered problem solving according to Friege (2001, Friege and Lind 2006) or the importance of basic physical principles in solving physical problems (Krause, 2013) should be mentioned.

GM: On the one hand, the many years of experience in mathematics didactics for problem-solving can provide profitable insights into physical problem-solving processes and competencies. On the other hand, application-oriented problem-solving processes, in particular, can be examined more closely in teaching mathematics by physics education research.

VP: A problem solving model consisting of three phases and problem-solving strategies are recommended by Nguyễn et al. (2002). The theory of problem-solving teaching method under the consideration of psychological and natural science cognitions methods is introduced in detail by Phạm (2007). The study of comparisons with project based learning is introduced by Trần (2010). Problem-based learning (PBL) is mentioned by Đỗ (2012). Recent outstanding research contributions include comparisons with the Lamap teaching perspective (Nguyễn & Đỗ, 2016), problem solving in integrated teaching (Nguyễn, 2016) and introduction of students' problem solving competence (Đỗ et al., 2019; Phạm et al., 2018).

VM: In mathematics education, Nguyen (2017) mentions two popular ways to create a problematic situation and solve problems. He uses Pólya's idea to propose four steps to solve a problem: understanding the problem, find a solution, present the solution, and looking back to the problem (Nguyen, 2017). Researchers also discuss some other methods to help students in the problem-solving process such as closed-open approach (Tran, 2018), software-based modelling methods (Nguyen, 2018; Tran et al., 2014), intuiting approach (Vo, 2018), or method of building learning situations in mathematics to develop competencies of solving problems in real-world contexts (Pham et al., 2018a).

Arguing and Proving

GP: In physics lessons, argumentation and proving are implicitly relevant in the competency areas of communication and evaluation. Reasoning plays a central role in physics (Jiménez-Aleixandre, 2007). In physics didactic research, this is usually located at the interface between theoretical hypothesis and experimental data or observations with the question of when and how empirics and theory reinforce or correct each other. Empirical studies also deal with the argumentation ability of students of physics (e.g. Böttcher & Meisert, 2011).

GM: In the curricular guidelines for mathematics teaching, argumentation and proving are usually presented as explicit process-related competences, since mathematics is regarded as the proving science. This is reflected in the mathematics didactic research on this topic (e.g. Hanna & de Villiers, 2012).

VP: The analysis of arguing and proving types accompanying with a corresponding solution to encourage students to implement is presented by Nguyễn and Nguyễn (2001) and Nguyễn et al. (2002). The role of arguing and proving in teaching physics is introduced by Phạm (2001). Đỗ (2006) provides the scientific basis of arguing

and proving, and applications in physics teaching. Trần (2016) analyzes a type of arguing and proving related to analogical reasoning in the history of physics.

VM: According to Nguyen (2017), to develop abilities to understand, present and perform proofs, it is necessary to train logical thinking, exact language capacity, prediction, imagination capacity, and also intellectual activities. Bui (2011) discusses how to teach students to argue and prove when they learn some specific mathematical knowledge. Dao & Tran (2010) mention two types of arguments in students' cognitive activities and emphasized the important role of arguing in the problem solving process.

From the authors' point of view, the comparison of mathematical and physical work on the subject of argumentation and evidence is very fruitful, since it allows discussion of similarities and differences in the concept of truth. This opens a valuable reflection of the respective subject. Closely related to this, is also the comparative discussion on beliefs about mathematics and physics (Section "Beliefs about mathematics and physics"), which can be conducted more specifically on the subject of argumentation and proofs than if the comparison of different views is conducted only on a meta-level.

Experimentation

GP: In physics, an experiment is the observation and measurement of physical processes and objects under defined and controlled conditions in order to acquire knowledge. It is regarded as the fundamental justification instance in the scientific theory-building process. At school, the experiment has also many other functions besides the qualitative and quantitative verification of theories, e.g. the visualization of physical phenomena, the arousing of interest and the learning of scientific work. The didactic research deals among other things, with the functional aspects, the correct use and development of new innovative experiments for teaching (Girwidz, 2015a).

GM: In recent years, mathematics didactics has also become increasingly intertwined with experimentation. Mathematics is generally regarded as a deductive science, but some of the ways in which new knowledge is created are experimental. In contrast to physical science, however, only formal proof represents a final instance of justification. Thus, the function of the experiment in mathematics teaching is limited primarily to the generation and preliminary testing of hypotheses (Philipp, 2013).

VP: Nguyen and Nguyễn (2001) analyze the leading role of experiments in experimental methods, which play a decisive role in the discovery of knowledge of the natural world, and introduce a teaching method simulating experimental methods including five stages. Pham (2001), Nguyen et al. (2002) and Pham (2007) classify the types of experiments and recommend corresponding ways of teaching physics. Out of the important role, the designing, setting up and conducting of experiments are both considered as research topics (Mai & Ngô, 2016) and are also considered as subjects to be learned by students (Nguyễn & Trần, 2018).

VM: Nguyen (2017) emphasizes the role of experimentation in the process of forming and developing mathematical knowledge. He concludes that not only deduction but also predictions and experimentation should be included in teaching mathematics to achieve the comprehensive educational goal (Nguyen, 2017). Tran et al. (2014) use a software to do some experiments. Therefore, the students can predict the result and approach the mathematical concept.

The exchange about the role of experimentation in the respective discipline can provide important insights into the development of knowledge of the subjects. In particular, mathematics teaching can profit from the rich research results of physics didactics for experimenting.

CONCLUSION

The intention of the authors is to use this article to promote cooperation between mathematics and physics didactics in the fields of research and teaching and to identify possible research topics for cooperation between the two disciplines. The listed topics are considered here as examples, as a common basis on a content foundation. The results of the explication of potential interdisciplinary fields of work only reveal different points of contact for possible joint teaching and research projects between mathematics and physics didactics. Thus, related topics could be identified, a more detailed analysis of them could not be realized within this contribution but seems to be worthwhile. Therefore, these points of contact may be seen, for example, as suggestions for formulating interdisciplinary research questions, or as a starting point for discussing the curricular content of interdisciplinary courses. However, the qualitative method itself presented here can also serve as a model for analyses of the identification of related topics between other subject didactics in the STEM field, between subject didactics and their related disciplines or beyond.

The following research desiderata should be addressed on the basis of the research results of this article:

- The explication described in "Comparison with the Vietnamese Literature" of contents that are relevant for both mathematics and physics didactics should be consolidated by separate publications by experts from both disciplines.
- The synergies of educational research of both subjects should be implemented in the corresponding teacher training programs. These team-teaching interventions should be designed and evaluated accordingly.
- The effect of such collaborations on the professional growth of the involved persons (teachers, teacher educators and scientists) needs to be investigated. The development of professional growth is a main goal of teaching and highly relevant in current research.

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APPENDIX

Table 4. Categories and examples of structuring analysis

Main Category	Category	Paradigmatic Examples	
		Germany	**Vietnam**
Mathematics and physics education research as scientific disciplines	C1.1: relevance of mathematics and physics	Loos & Ziegler (2015) Kircher (2015)	Nguyễn (2002) Bùi (2018)
	C1.2: Mathematics and physics education research as scientific disciplines	Struve (2015) Kircher (2015)	Nguyễn (2002) Nguyễn (2017)
	C1.3: Beliefs about mathematics and physics	Rott et al. (2017) Roetger & Wodzinski (2017)	Nguyễn (2001) Nguyễn (2017)
	C1.4: History of mathematics and physics (in class)	Schorcht (2017) Heering (2013)	Đào (2003) Nguyễn et.al (1994)
Educational research theories	C2.1: Didactical principles	Reiss & Hammer (2013) Kircher (2015)	Nguyễn (2002) Nguyễn (2017)
	C2.2: Preconceptions	Lamprecht (2017) Wiesner et al. (2011)	Đỗ (2014) Nguyễn (2017)
	C2.3: Subject-matter didactics	Vom Hofe et al. (2015) Müller (2015)	Nguyễn (2002) Nguyễn (2017)
Goals and Competences in Mathematics and Physics Teaching	C3.1: Goals and competences	Reiss & Hammer (2013) Kircher (2015)	Đỗ (2019) Trần (2015)
	C3.2: Model / Modeling / Applications	Kaiser at al. (2015) Kircher (2015)	Nguyễn (2001) Vũ (2015)
	C3.3: Concept development	Weigand (2015) Wiesner et al. (2011)	Nguyễn (2002) Thịnh (2014)
	C3.4: Problem solving	Heinrich et al. (2015) Brandenburger et al. (2014)	Nguyễn (2001) Nguyễn (2017)
	C3.5: Arguing and proofing	Jahnke & Ufer (2015) Ludwig & Priemer (2018)	Đỗ (2006) Nguyễn (2017)
	C3.6: Experimenting	Philipp (2015) Wiesner et al. (2011)	Nguyễn (2002) Trần et.al (2014)
	C3.7: Communication and language	Jörissen & Schmidt-Thieme (2015) Rincke & Leisen (2015)	Đỗ (2014) Lê (2015)
Teacher Training	C4.1: Teacher training / teacher professionalization / teacher competence	Krauthausen (2018) Fischler (2015)	Phạm (2016) Dao & Nguyen (2015)
	C4.2: Science labs / Teaching and learning laboratories	Lengnink & Roth (2017) Euler et al. (2015)	Nguyễn (2018) NV
	C4.3: Transition from school to university / start of studies	Büchter et al. (2017) Krause (2016)	NV Hoàng & Phan (2015)
Teaching practice and pedagogical topics	K5.1: Planning, analysis and organisation of lessons	Leuders (2003) Kircher (2015)	Nguyễn (2002) Nguyễn (2017)
	C5.2: teaching methods	Ufer et al. (2015) Kircher (2015)	Đỗ (2012) Nguyễn (2017)
	C5.3: Performance assessment and diagnosis	Opitz & Nührenbörger (2015) Wiesner et al. (2011)	Đỗ (2019) Phạm (2015)
	C5.4: Media	Leuders(2003) Girwidz (2015b)	Nguyễn (2002) Trần & Nguyễn (2015)
	C5.5: Differentiation / Heterogeneity / Inclusion	Bruder et al. (2015) Heuling (2017)	Đỗ (2012) Phạm et al. (2015)
C6: Tasks		Reiss & Hammer (2013) Wiesner et al. (2011)	NV NV
C7: Interdisciplinary collaboration of mathematics and physics education researchers		Holten & Witzke (2017) Krause (2017b)	NV NV

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