Teaching Didactics of Informatics to Secondary School Informatics Student Teachers

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Abstract
In this paper, the authors introduce an innovative conception for a lecture course "Didactics of Informatics I", in which Informatics student teachers learn teaching technical Informatics concepts to students of different secondary school types. Therefore, the organization of the German school and teacher education system is sketched at first. Afterwards, substantive requirements for such a course are derived and linked with organizational settings. On this basis, the course conception is founded and first experiences with its implementation in the Informatics teacher studies are described. Finally, the authors discuss the potential of the approach for web-based training courses for teachers in Informatics, for which there is in many federal states still a great need.

Keywords
Informatics teacher education, Didactics of Informatics, Active learning, Secondary education, Blended learning, E-learning, Notebook university

MOTIVATION
The responsible, thoughtful and purposeful use of modern Informatics systems is considered by many as a fourth cultural technique in addition to reading, writing and arithmetic. Informatics as a subject that mediates these and other skills is well established in Germany almost everywhere at least as an optional subject and in some federal states as a compulsory subject for all pupils (Hubwieser, 2006). Good Informatics education requires well-trained teachers. At many universities there are, therefore, Informatics teacher training courses in which the skills required for a job as an Informatics teacher at a secondary school are acquired. Furthermore, there are many teachers who are already teaching Informatics in schools, without having a teaching certificate for that. For these there is a continuing need for in-service teacher training. Core of the subject-specific training for teachers is the didactic training, in which teaching of Informatics concepts to students of certain secondary school types and age groups is the focus. To this issue is the paper at hand. A didactic training at a university must meet scientific standards on the one hand, and also prepare adequately for a practical activity as an Informatics teacher on the other. All this could of course take the form of a traditional, lecturer-centred course. In this paper, the authors outline, therefore, an innovative, student-centred and activating course concept, whose aim was and still is to not only meet the above conditions, but in particular to utilize specific and general didactic design options to full advantage to maximize the learning success of the students. Significant design directive was: if it is labelled with didactics, there should also be didactics in it...

THE GERMAN SCHOOL AND TEACHER EDUCATION SYSTEM
In Germany, the teaching certificate program is a separate study that can be studied at many universities. In general, two subjects are studied including the related
didactics and general educational components. The teaching study is directed to a particular school type.

In secondary education, there are four main types of schools in Germany: grammar schools (“Gymnasien”, grades 5-12, 11-18 years old) with a broad general education, general studies and academic preparation in the last few years of schooling, middle schools (“Realschulen”, grades 5-10, 11-16 years old) with a sound general education and vocational preparation, and “Hauptschulen” (grades 5-10, ages 11-16 years) with a basic general education and sound vocational preparation. The latter prepares for an apprenticeship and is significantly more practice-oriented than the other school types. Furthermore, mixed school types exist, such as so-called “Mittelschulen” (middle schools) and “Gesamtschulen” (comprehensive schools). Finally, there are also professional schools (“Berufliche Schulen”), which are usually attended during an apprenticeship.

The studied school type is reflected in the selection of specialized and pedagogical modules as part of the study, in the design of the didactic modules, and in the length of study. In the federal state of Bavaria in southern Germany, for example, the teaching study for grammar schools is designed for 9 semesters, while the study for all other schools types is designed for only 7 semesters. To date, the teaching study prepared for a First State Examination at the end of the study, which is seen as an entrance examination for the subsequent student teaching phase (“Referendariat”, one to two years). Some states have already transferred their teacher education programs into bachelor and master structures and use the Master of Education (M. Ed.) as an entrance requirement for the student teaching phase (see above), in other states this transition process has just started or is still underway.

A teaching study program typically has the following structure. In the first semesters the professional (of each subject) and educational basics are learned. After the first one to two years of study the specialized didactic training starts, which is – besides others – about selecting, didactic preparing, and teaching professional scientific content for students of a particular school type and age group considering educational knowledge such as teaching models or teaching methods.

**SPECIALIZED DIDACTIC EDUCATION OF STUDENT TEACHERS**

Education is organized federally in Germany. Since the findings of the PISA studies, however, in all fields of education a shift from a federal input to a central output orientation can be observed. This is reflected for example in the development of national educational standards for many school subjects, for example, in computer science (Brinda et al., 2009). But also for teacher education standards have been developed. For example, the Association for Fachdidaktik (German national association for specialized didactics, “Gesellschaft für Fachdidaktik, GFD”) published a core curriculum for the design of specialized didactic modules for teaching studies in 2004 (Association for Fachdidaktik, 2004). The competencies to be acquired as part of the specialized didactics education are structured into modules as follows:

**Module I: Subject reflection and communication skills**

1. Ability to reflect on the meaning and development of the subject or subjects involved
2. Ability to reflect the basic structures of the communication process between science, didactic research and public
3. Capacity for exploration and critical analysis of relevant professional practice fields
4. Planning and implementation capacities of technical knowledge in selected practice areas, including critical review and further development
5. Specialized communication and teaching skills

**Module II: Didactic lesson-oriented basic competencies**
1. Ability to reflect the respective characteristics of professional teaching and learning
2. Ability to assess the teaching and learning in their subject / learning area in the historical change, ability to evaluate the objectives and content of the subject (ethical and social criteria)
3. Ability to clarify personal values and attitudes toward school, teachers and the teaching profession and ability to biographical reflection of specialized education and learning experiences as well as for the projection of subjective counterdrafts
4. Ability to (re) construction of professional knowledge with the aim of being able to plan and implement appropriate lessons in a theory-oriented way
5. Ability to observe, survey and evaluate essential structural elements of professional teaching and learning processes as well as for testing individual abilities to act in the lesson

**Module III: Didactic lesson-oriented action and evaluation competencies**
1. Ability to learn and epistemological model professional teaching and learning (under consideration of current positions)
2. Ability to exemplary reception of didactic research work, methods and results and their (ethical) review
3. Ability to reflect and review of existing teaching approaches and to develop innovative / interdisciplinary teaching approaches and methods
4. Capacity for reflection, evaluation and implementation of recent professional knowledge into didactic methodological appropriate instruction
5. Knowledge and application of the broad empirical research on teaching and profession-oriented action research
6. Ability to third party and self evaluation under consideration of diagnostic thinking and knowledge

These recommendations provide a national coordinated framework for competencies to be acquired in context of a didactics education. They form an essential design framework for a theory-driven design of a lecture entitled "Didactics of Informatics I".

**REQUIREMENTS TO A DIDACTICS EDUCATION IN INFORMATICS**

**Content-related requirements**

The goal of an Informatics teaching certificate is to prepare students the best possible and scientifically to work as an Informatics teacher at a certain secondary school type (see above). From this we can deduce the following requirements to a didactics education in Informatics:

1. Informatics teacher education should be scientifically founded in the fields of the science Informatics itself, pedagogy, and didactics of Informatics.
2. The student teachers should be activated best in class in order to maximize their learning success. They should acquire pedagogical knowledge and teaching skills also by the fact that they operate in a didactically designed course scenario.
3. The students should be introduced to typical educational media (such as learning management system with wiki and forum, notebook with school-
relevant software, interactive whiteboard etc.). This is achieved by the fact that they experience the media use in the classroom prototypically in the course.

4. To implement the general competency goals of teacher education, in order to contribute to the standardization in the field of teacher education in order to thereby improve the comparability of education between the universities, it is guaranteed over the entire Informatics teacher education that the competencies formulated in the didactics core curriculum are reached.

**Organizational Requirements**

The extent of didactic education varies between the German federal states to a considerable extent in some cases. In the federal state of Bavaria, for example, 10 to 12 ECTS points (grammar school: 10 ECTS points, all other school types: 12 ECTS points) are assigned to the subject-specific didactic training by the federal teacher examination regulations. In Erlangen, this has led to two courses "Didactics of Informatics I" and "Didactics of Informatics II" (both 5 ECTS points) for all students and an additional seminar (2 ECTS points) for students requiring 12 credit points in specialized didactics. In addition to the subject-specific didactic units there are different school internships which each student has to pass in one of the chosen subjects.

**CONCEPTION OF THE INTRODUCTORY COURSE “DIDACTICS OF INFORMATICS I“**

**Content structure of the course**

In terms of the science Informatics and general pedagogy, science orientation will be assured in the corresponding lectures. Since the objective of the didactic training is the scientific preparation for a career as an Informatics teacher, a scientific model of analysis and planning of instruction can and should be used as a theoretical framework for the didactics education. Well suited is here the so-called Berlin model for analysis and planning of instruction (by Heimann, Otto and Schulz, described in Ulijens, 1997), as it is clearly structured and well comprehensible, and includes both the variety of basic conditions and design fields in the lesson analysis and preparation.

The Berlin model distinguishes between conditional and decision areas of teaching: in the condition fields anthropogenic and socio-cultural context are taken into account and in the decision areas the learning objectives, topics, teaching methods and media are considered. The theory of didactics of Informatics (as published, for example, in Schubert and Schwill, 2004; Hartmann et al., 2006; Hubwieser 2007 and the proceedings of the conference series “Informatics and School – INFOS” by the German Informatics association (“Gesellschaft für Informatik – GI”)), is embedded in this structure. A major advantage is that in this way condition and decision-making areas are considered appropriately, moreover the students consolidate their general pedagogical knowledge and they experience a theoretical framework for their own teaching analysis and preparation, which ensures that no important aspects are forgotten.

Thus, in the field of socio-cultural requirements aspects of Informatics education in general, legal requirements for (Informatics) school education, because of social conditions developed didactic approaches to teaching Informatics (hardware-oriented, algorithm-oriented, user-oriented, information-centred, system-oriented, or context-oriented approach) as well as IT infrastructures in schools as a condition of Informatics education are considered. In the field of anthropogenic conditions findings from learning and developmental psychology in terms of Informatics, mental
models to Informatics concepts as well as gender differences in learning Informatics concepts are discussed.

In the decision-making areas of teaching, for example, in the area of the topic the selection of educational content in the area of Informatics, the process of informatics modelling as well as conceptions for introductory Informatics courses in schools are addressed. Talking about the objectives, specific learning objectives of Informatics, Informatics specific methods of learning objective analysis as well as competence and standard orientation in the field of Informatics are in the foreground. In the field of methods the application of general and Informatics specific teaching methods (such as group jigsaw, object game) is addressed, the section about media focuses on the analysis, design and implementation of specific teaching aids for Informatics education (such as standard software, learning software, software development tools, animations, videos, or educational games).

The course material is provided using a Learning Management System (LMS), which in this case is Moodle, www.moodle.org.

**Activation of the student teachers and media-design**

The maximal activation of the student teachers is achieved taking into account findings from university didactics. At any time the question will be asked of whether something that would do the lecturer could not make even the students themselves. The course material (see above) is assigned to the weekly meetings.

**a.) Preparation of the meeting**

All course units start with competence-oriented learning objectives. The students receive all material (slides, tasks, web sites) about a week before each course date and prepare it with regard to the learning objectives by themselves. For selected topics in addition to or alternative scientific texts are provided via the LMS to prepare. In the LMS a public forum is set up to the course material in which questions and / or comments can be submitted.

**b.) Face-to-face session**

The face-to-face session starts with a brief summary of the lecturer on the main issues of the provided material. Some such short presentations are also assigned to students. The students then have the opportunity to ask questions to the course material to the lecturer. If these are resolved, working on the subject issues starts. The students get presence tasks derived from the learning objects of the unit via the LMS, which they complete using activating teaching methods (e. g. group puzzle, role play, project method) in teams. For that laptops are available, but they can also use their own units. Students login via WLAN to the LMS, and co-operatively produce texts and illustrations, which they put directly into a wiki provided in the used learning management system Moodle. This has the advantage that all results of all sub-groups are available to all other participants after the session. Moreover, blended learning and notebook university conceptions are implemented this way. Finally, the results will be presented and discussed in plenary on an interactive whiteboard. Using a digital pen the solutions of the participants are annotated and commented when needed, these annotations are stored as a PDF document and made available on the course wiki as supplementary learning resources. The objective of this phase, it is on the one hand that the students test the practical application of course material. They will advise on emerging issues and difficulties with each other and with the instructor and determine in this way, whether they have understood the material. On the other hand they should experience activating teaching methods as well as for Informatics classes typical media (such as LMS with wiki and forum, notebooks with typical software, interactive whiteboard) in their own
educational process as a participant, so that they can incorporate this experience into the design of their own lessons.

c.) Homework assignments
Students will receive weekly written homework assignments (e.g. creation of lesson plans, preparation of teaching-learning materials, etc.) that they will individually complete. They submit their results electronically via the LMS as file uploads. Peer review is used as a didactical method for appropriate tasks, such as the creation of Informatics lesson plans. This is technically well supported by the LMS Moodle with the so-called workshop activity. Each electronic submission will be forwarded to, for example, two participants for comment. The participant will receive the feedback from other students who had to analyze his submission before, and can respond to them. Besides the submissions the tutor now also has the commentaries available for assessment. The submissions and commentaries are finally evaluated by the tutor via the LMS, the average score of about the best 75% of each participant’s homework submissions constitutes around 60% of his or her module grade. In this way, the students are motivated to the end of the course to do their homework. The results will then be presented and discussed in the face-to-face session; selected solutions of the participants are published on the LMS anonymously as reference solutions.

d.) Final presentation
The students receive at the end of the semester the task based on the lecture’s main objective to design an Informatics lesson sequence for their individual school type and a topic of choice of approximately eight to twelve hours. They should draw connections to the course material as detailed as possible and document in this way that they are able to practically implement the theory. It is organized using the LMS wiki that the same topic is not selected by two students. The presentation and discussion takes place on a block event, all presentations are then made available to all participants via the LMS, so that they also benefit from the work of others. The final presentation constitutes another 30% of the final module grade; the remaining 10% are constituted by the individual activities in the face-to-face sessions. This stimulates the participants’ activity.

Competence Orientation / Didactics core curriculum
The “Didactics of Informatics I” lecture can be characterized by the fact that it develops in an innovative, integrated manner professional, didactical, methodical, media pedagogical and key competencies. This is achieved by a lecture conception which integrates these competence fields and which is transferable to many other areas not only within teacher education (also further education). Over the entire range of Didactics of Informatics lectures it is guaranteed by means of the “Didactics core curriculum” of the Association for Fachdidaktik that all competence areas which are relevant for teacher education are covered. The student experience, for example, the use of general and subject-specific teaching methods in their own learning process and also deal with them theoretically in the course. This strengthens the action and methodological skills of the students. Through the design of Informatics lessons as part of the exercise phases using such teaching methods, they reflect their possible applications with regard to such lesson scenarios. The development of the competencies of the students is supported by the methodical and the media conception of the lecture, which stresses their activation among the entire semester. Throughout the course the students have to use technical language to discuss subject-related positions with each other and to develop ideas for solutions, cooperate, and apply systems and thus also acquire relevant key competencies.
First experiences

a.) Quality of work results
The quality of the work of the students, especially the homework and the final presentation reached a very high level in 2009, which indicates the achievement of the course objective.

b.) Student lecture evaluation
The course "Didactics of Informatics I" is offered at the University of Erlangen-Nuremberg since summer semester 2005, at the Technical University of Munich since 1997. Starting with a traditional lecture scenario with built-in exercise units, the proportion of student activity in subsequent years was gradually increased to the extent described in this paper. Gradually also activating teaching methods were included. The integration of laptops, interactive whiteboard and LMS was done for the first time in the summer semester 2009.

Since the course "Didactics of Informatics I" is offered in Erlangen, the results have steadily improved in student lecture evaluations. In Erlangen courses are categorized differently (mandatory courses, optional courses, etc.) and rankings are made regarding these categories. 2007 and 2008 the lecture conception reached place 2 in the high score, in 2009 even the 1st place (see http://ddi.informatik.uni-erlangen.de/teaching/eval.html). Some comments of the students (2009):

"Specialized didactics lecture, in which one really learns something."
"Compared to other courses with 5 ECTS points very laborious."
"Good lecture with illustrative slides. Despite the high time required a course which I gladly attended."

At the Technical University of Munich the course was given the mark 1.78 (1.0 is the best, 5.0 the worst mark) in the last evaluation in 2010. The students appreciated in their comments particularly the orientation towards practical teaching and the opportunity to participate actively.

The students evaluate the course to be very labour intensive, but show good to very good performance and recognize that they have learned in the course a lot. All these are indicators of the success of the course conception.

POTENTIAL FOR THE IN-SERVICE TEACHER TRAINING IN INFORMATICS
Nationwide, there are still too few qualified Informatics teachers for secondary schools. The fact that Informatics is a mandatory subject for all students only in a few of Germany's federal states causes that Informatics teacher education is in many places not yet fully developed. But even where there are mandatory or optional Informatics classes in secondary schools, there is often a short-term demand for teachers with teaching qualifications in Informatics, which is usually certified by the First State Exam in Informatics. To address this deficiency, there were and are in many federal states professional qualification offers for teachers of other subjects to Informatics teachers (Spohrer, 2009). As part of a typical two to four years of postgraduate studies the participants acquire the skills necessary for work as an Informatics teacher. To ensure compatibility with the profession and to keep costs through presence low, also e-learning courses are used. In the federal state of Bavaria postgraduate teaching studies in Informatics is implemented using specialized e-learning modules developed for this purpose. An e-learning implementation of a “Didactics of Informatics” module is not available yet.
Subsequently, the conception of the lecture course "Didactics of Informatics I" (see above) is analyzed for its e-learning potential. The authors assume that a standard learning management system (LMS), such as Moodle (see www.moodle.org), is used for the e-learning implementation.

**Content structure**
The reasoning of the content structure followed only logical considerations, but in no way taking into account the lecture’s face-to-face scenario. There is therefore no need to adjust this structure.

**Teaching material**
As teaching material so far the presentation slides, tasks, and links were provided as well as additional scientific and educational texts for selected chapters. For a pure e-learning scenario, the possibility would be to provide a corresponding audio comment for the slide stream using appropriate screen recording software, such as Camtasia (see www.techsmith.com) or Lecturnity (www.lecturnity.com), of which the standard lecture scenario would also benefit. A disadvantage is that when the slides are changed the audio commentary should also be adjusted. In the traditional lecture the students must have completed this material as a preparation of the presence scenario, which would be analogously possible in the e-learning scenario.

**Counterpart to the presence scenario**

*a.* **Lecture summary**
The face-to-face scenario starts with a short lecture summary given by the lecturer. A concise summary can also be integrated into the recorded slide stream, possibly provided as a separate document in order to have direct access.

*b.* **The opportunity to question**
There are several ways: in an asynchronous scenario a forum might be a good idea. A target date will be set by which questions may be submitted to the course material. Answering questions and discussion takes place with the participation of all participants and the lecturer. The contributions of the participants will be included in the assessment. This stimulates the discussion. Alternatively, it would be possible using a wiki. The disadvantage here was that it would be difficult to assign individual contributions to the participants. In the synchronous scenario (arrangement to meet to clarify issues at a specific date) a chat, audio or video conference would be possible. The latter requires appropriate hardware on the participant side. To directly answer longer questions a chat is cumbersome and only limited suitable. All media (chat, conference) could be recorded and contributions of the participants could be included in the assessment in this way. But this is potentially very costly.

*c.* **Work of participants on the subject matter, using activating teaching methods**
Here, the participants should complete different tasks on the subject matter in potentially changing groups using activating teaching methods and media (see above). The results should be entered in a wiki that is open to all participants. The LMS Moodle offers the opportunity to begin working with separate groups so that the participants produce material in their groups at first and the results will be made only after completion of all available. For communication of the teams there are individual chats, video conferencing, telephone, or a forum. This forum is available only for the particular group and the tutor. Furthermore, a public forum is set up, in which questions arising during task completion can be asked to all participants and the tutor. The contributions of the participants are taken into account in the assessment. This encourages the activity of the participants. Furthermore, activating teaching
methods (such as pair work, group puzzle, project work), which are well-known in the presence scenario, are conveniently transferred to the e-learning scenario. For that matter, computer supported collaborated learning tools, such as collaborative mind mapping tools (e.g. Mindmeister, www.mindmeister.com), are used.

For the assignments of the participants, a deadline is agreed. In the face-to-face scenario, the results are then presented and discussed in plenary. For the e-learning scenario, it is conceivable that the team members create a presentation (three to five minutes) and record it using free screen recording software (such as CamStudio, www.camstudio.org). For more group members, the presentation may consist of several components that have been created each by one team member. These materials are placed in an appropriate manner on the learning platform for all participants. At the same time the results will be published for all participants. Each participant is given the task to deliver a brief comment for two results of other participants. By means of appropriate tools (e.g. a wiki) it is organised that all results receive approximately the same number of comments from other participants. These comments are relevant for assessment and need to be delivered at a specific time. The creators have the opportunity to respond to these comments. The tutor gives a final comment, if this is required due to the contributions to the discussion. If changes to the current result document are required to be submitted, they are entered and adequately emphasized.

Homework assignments

a.) Completion and submission

Individual homework assignments are individually prepared and submitted via the submission system of the LMS by file upload. For the answering of questions a public forum is available. This represents no change compared to the presence scenario. Forum posts are again relevant for assessment. All submissions will be individually corrected, annotated and graded. With the participants it will be individually agreed, if all solutions including the accompanying comments of the tutor or just the n best (all anonymous) will be published for all participants. The publication of all solutions also enables learning from mistakes. Furthermore workshop activities remain directly implementable, in which the students receive n solutions from other students to comment on (peer review), which will develop analytical competencies in addition to just constructive ones. That is, for example, an appropriate technique when creating Informatics lesson plans.

b.) Presentation

If one wanted to replicate presentation of solutions in the presence scenario, this could be also done by means of suitable screen recording software. The forum on the homework assignments could then be also used to comment on and discuss solutions. In this case, the feedback of the tutor should be published only after the conclusion of the discussion.

Final presentation

The final presentation is created individually by each participant. The presentation can be created as a screen video and be uploaded to the learning platform. Clarifying issues and discussion of results is the same as mentioned above.

Module completion

The problem of the e-learning scenario is to ensure the mapping of any course achievement to an individual student, because he or she could have had relevant third party help. For this reason, in a pure e-learning scenario it must be recommended to finish the module with an oral examination, either in presence or in a secure environment via video conference.
CONCLUSIONS
In this paper an innovative conception for an introductory lecture on "Didactics of Informatics" was presented. In this conception in an innovative way technical, didactical, media education and key competencies of the students were developed. The basic course conception is not only transferable to all areas of didactics of Informatics, but also to other specialized didactics, and beyond. This also applies to the outlined implementation as an e-learning module. The work results of the students as well as their feed from the lecture evaluation are indicators of the success of the lecture conception.

REFERENCES

BIOGRAPHIES
Torsten Brinda studied Informatics at the University of Dortmund (Germany) until 1998 before he worked as a scientist in the "Didactics of Informatics" groups at the Universities of Dortmund (until 2002) and Siegen (2002 to 2005). In 2005 he became an associate professor for "Didactics of Informatics" at the University of Erlangen-Nuremberg. Since 2008 he is vice chairman of the Centre of Teacher Education of the University of Erlangen-Nuremberg.
Peter Hubwieser is an associate professor at the Technical University of Munich. He initiated and decisively designed the new mandatory subject of Informatics at Bavarian Gymnasiums from 1994 to 2007. In 2008 he was given the task of elaborating a core curriculum for teacher education in Informatics by the "Deutsche Fakultätentag" (the Union of all faculties in Germany). Since 2009 he is a member of the innovative School of Education at the Technical University of Munich.