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# A Teacher Education Approach for Integrated Science Instruction

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## Abstract

*Integrated science education – the combination of the subjects Biology, Chemistry and Physics – and its implementation for the German school system is currently being discussed. Various implementations of integrated science curricula exist in the different federal states for students ranging from grades 5 through 10. In Germany, teacher education at the university level and in teacher training centers focuses on the individual subject. Pedagogical content knowledge is taught at university level within the disciplines Biology Education, Chemistry education and Physics Education instead of science. In particular, teacher education programs are organized according to these subjects and do not properly prepare for the demands of integrated science instruction.*

*The development of a qualification certificate of 16 ECTS for university students in a Bachelor and Master of Education program is presented. To participate in this program students have to be enrolled at least in one of the natural sciences as their future teaching subject. Within the certificate program they will then take introductory classes covering content knowledge of the remaining disciplines. As the depth and rigor of an entire discipline cannot be implemented within the scope of such a program, a focus needs to be elaborated. Students will be introduced to foundational concepts regarding pedagogical content knowledge of areas they did not study before and to the concept of scientific literacy as the overarching link between all three natural science subjects. After that participants design a teaching-unit on integrated science topics in interdisciplinary groups and put these units into practice within a school setting.*

*The certificate aims at better preparing pre-service science teachers for an integrated science education by fostering the ability to extend their content knowledge and to enhance their pedagogical content knowledge with respect to all sciences. For this objective best practice teaching-units improve content knowledge and pedagogical content knowledge for integrated science education.*

## 1. Science Education in Germany

In Germany, science education for the lower secondary level (“Gymnasium”) is traditionally separated into the subjects of Biology, Chemistry and Physics and starts at grade 5. This distinction follows a general approach on natural and social sciences in elementary school. Consequently, not all three disciplines might be taught at the same time and, more importantly, by the same teachers. The early separation of disciplines can lead to separate academic self-concepts [1]. In recent years, some federal states, school forms or even individual schools have chosen to teach science in an integrated manner, often with differing organisational structures [2, 3]. The rising school form of “Integrierte Gesamtschule”, which also leads to the general higher education entrance qualification, practices science instruction in this way. For a detailed description of the German School system see [4] and for Science Education in Germany see [5, 6].

Science, whether taught in separate disciplines or in an integrated manner, always aims at developing both skills and knowledge. Within the German national educational standards for the natural sciences, these two dimensions are structured as process and content oriented competencies. In contrast to some international approaches (e.g. basic standards in Switzerland), the German system defines broadly what students should achieve at the end of grade 10, without being founded on empirical evidence [6]. The aim to develop and strengthen student’s interest in science as an effective goal remains undisputed since a positive relation between interest and performance is commonly believed to exist [7–9]. Embedding science education into meaningful contexts seems to be one (promising)

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way to link student's interest, societal issues and science education [10, 11]. However, it seems challenging to balance both context and development of basic concepts effectively [12].
Advantages associated with an integrated instruction of natural sciences are manifold and common internationally [13–15]. They include but are not limited to the following; integrated instruction as a constructivist approach leads to more meaningful connections of newly accumulated knowledge. It provides learners with richer opportunities to establish connections between new insights and previous knowledge. Regarding, for example global challenges it is argued that multidisciplinary approaches are necessary to describe the full scope of problems and to foster problem solving skills. Placing the instruction's topic within a (life-related, ethically challenging) context is believed to improve student interest [16, 17]. This especially concerns the group of girls who is otherwise found to be less enthusiastic about science. Thus, integrated instruction can contribute to a gender-sensitive classroom [18]. Furthermore, integrated instruction promotes a broader set of skills useful for the professional world like aquiring a tolerance for ambiguity.
However, it has to be noted that many of the advantages commonly listed in the literature are only seldom approved by empirical evidence. In fact, the few studies that have been carried out comparing integrated to disciplinary science instruction yield a rather balanced account of student performance. Systematic review of the few studies on the issue showed similar performances of both groups but motivation was improved in the integrated groups and the gender gap could be successfully reduced using integrated science [19]. A comparison of the Swedish PISA data revealed no particular differences between the performances of students taught either integrated or in the traditional way [20].Broadly speaking, one might conclude that the label *integrated* alone does not necessarily distinguish the instructional pattern from traditional teaching and that a closer look at the qualitative differences is needed as well as a focus on the education of the educators themselves.

## 2. Teacher Education for the Natural Sciences

Unlike numerous other countries, high school teachers (children aged 10-18, grade 5-12) in Germany usually study two subjects which they later teach at the high school level. Therefore, efforts and learning time at university level has to be split between two subjects and their pedagogical content knowledge (PCK). Depending on the federal state and individual university regulations only certain combinations of subjects are valid for studying. For example, combinations include natural as well as social sciences or foreign languages. Actually, a positive relation between the teacher's expertise reached at the university level and their students' performances [21] and the type of instruction [22] could be shown. The amount of university level coursework of teachers further positively affects their students' self concept [21]. Additionally, university students tend to socialise themselves (and rightfully do so) with their specific discipline which they can consequently convey in school settings. Moreover, the distribution of subject teachers is imbalanced [23]. Integrated instruction, however, needs a balanced approach regarding the whole spectrum of science. The concept of scientific literacy offers a framework linking the disciplines [24]. Concerning integrated science instruction certain problems are evident and challenge decision makers at all levels from classroom instruction to teacher education to the educational system [25].
Some approaches in the context of integrated science teacher education of course have been tried; A Swiss degree programme aims entirely at teaching natural sciences both separated and integrated, however only for grades 7 to 9 [26]. Furthermore, a German degree programme for science teachers for elementary school level and grade 5 and 6 was proposed [27].

## 3. Approach for Teacher Education aiming at Integrated Science Instruction

The additional qualification certificate of 16 ECTS for university students in a Bachelor and Master of Education programme for high schools with grades 5 to 10 is depicted in Figure 1. Participants are only eligible if they study at least one natural science as one of their future subjects at school. The certificate consists of three pairs of basic content knowledge (CK) and pedagogical content knowledge courses in the respective sciences. Within the programme students first take introductory classes designed to make them familiar with school-relevant content knowledge of the remaining disciplines (2 ECTS). Topics are limited to those content and process oriented competencies found in the curricula

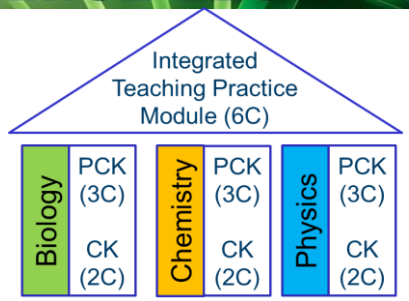


Figure 1 Structure of Courses, C= ECTS

of the federal states up to grade 10.
Students are also introduced to foundational pedagogical content knowledge in the remaining sciences. For this purpose they join regular students of this subject in their first courses aiming at pedagogical content knowledge (3 ECTS). After completing the courses in the respective disciplines, participants design a teaching-unit in interdisciplinary groups and put the unit into practice within a school setting. This integrated teaching practice module of 6 ECTS combines elements of a seminar where teaching-units are planned and modified based on discussion with peers and the practical experiences in an authentic school environment.
This approach introduces students to both of the formerly unstudied sciences with regards to CK as well as PCK to underline the common foundation of the natural sciences. While each discipline has its justified focus and strengths many of the basic processes involved e.g. in setting up experiments and observations aimed at measuring and interpreting data lie on a shared foundation of competencies [15].

Table 1 temporal structure of courses

| | semester | summer | winter | summer |
|---|---|---|---|---|
| 2 out of 3 | Biology | | CK | PCK |
| | Chemistry | CK | PCK | |
| | Physics | CK | PCK | |
| | | | | Practice |

Students are encouraged to finish the certificate within a period of three semesters as suggested in Table 1. However, it will be possible to split courses between Bachelor and Master programme.
Future steps include the implementation of the programme and its evaluation. The latter is based on different research tools and constructs. In addition to standard university questionnaires on course quality the achievements of competencies will be measured using post-course self-reports. Group interviews will accompany the participants in the practice module. The development of students' self-efficacy in distinction of their perceived role as teachers of integrated science instruction versus teachers of a specific subject will be monitored as well.
The certificate prepares pre-service teachers for their future tasks in integrated science instruction which becomes increasingly important in regular high schools and has become the overall concept in some school types ("Integrierte Gesamtschule"). Current university graduates are prepared to teach subjects separately. The certificate programme prepares for some of the challenges of integrated natural science instruction.

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