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Discussing the Context-based Approach IniK from the Perspective of Situated Learning Theories

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Abstract

"Informatik im Kontext (IniK)" is a recent pedagogical approach introduced for lower secondary (grades 5-10) computing education in Germany. The approach is derived from the context-based teaching approaches developed in science education. In this paper, we will introduce the theoretical framework of these approaches and discuss IniK in relation to them. Addressing the question of decontextualization and student interest, we will suggest possible directions for how the approach could be improved further.

1 Introduction

There is a tendency in the field of Computer Science (CS) education to adapt pedagogical approaches(we use the terms *CS education* and *pedagogical approach* referring to "Didaktik der Informatik" and "fachdidaktischer Ansatz", respectively) from other educational fields, especially mathematics or science education. A prominent example of this tendency is "Informatik im Kontext (IniK)", a German pedagogical approach that is meant for planning, accomplishing, and analyzing CS lessons in lower secondary (grades 5-10) computing education, which is derived from context-based approaches from science education. A young discipline like CS education can benefit from adapting approaches from more established fields. Despite this potential value, it is important to consider the conceptual framework and the addressed problems of both the original field and the destination field to which the transfer happens. In this paper, we will focus on the theoretical framework context-based approaches from science education are based on, and compare IniK with them. We will outline differences between the approaches and unsolved problems of IniK that are due to these differences. By addressing the question of decontextualization and student interest and suggesting possible solutions, we want to contribute to the ongoing discussion about the IniK approach.

2 Context-based Approaches in Science Education

The context-based approaches in the field of German science education include three different pedagogical approaches from chemistry, physics, and biology education named "Chemie im Kontext (ChiK)", "Physik im Kontext (PiK)", and "Biologie im Kontext (BiK)", respectively. Although there are differences among these approaches, they all share a family resemblance. For the purposes of this paper, the distinctions between these differently named research and teaching programs are not as important as their similarities. In this section, we will outline the initial problems that gave reason to develop these approaches and introduce the theoretical background they all refer to. For this purpose, we will focus on ChiK, which was the first context-based approach in science education and to which IniK is most directly related.

A decade ago, empirical studies revealed that "students' interest in science decrease[d] as they grow older" and in addition the international comparative studies TIMMS and PISA indicated "deficiencies in the acquisition of knowledge and conceptual understanding of German students" with regard to scientific literacy ([16], p. 1439). This was a starting point of several activities to bring in new pedagogical approaches to science education, among which ChiK is one. Addressing these fundamental problems, ChiK is the result of several insights into how learning is conceptualized and understood. For this matter, Chik was developed with regard to a theoretical framework that specifically focuses on a student-oriented conceptualization of learning processes. This framework includes a constructive and situated view of learning. Therefore, in order to understand the key characteristics of ChiK, it is important to focus first on this theoretical framework.

2.1 Theoretical Embedding of Context-based Approaches

The cognitive view on learning focuses on the question how specific knowledge is acquired and represented in the mind. Different forms of knowledge are distinguished as general or domain-specific knowledge, which includes "concepts, facts, and procedures explicitly identified with a particular subject matter" ([3], p. 49), as well as declarative ("knowing that"), procedural ("knowing how"), and conditional knowledge ("knowing when and why" to apply declarative and procedural knowledge) ([27], p. 258). In such a framework, learning is conceptualized as a process in which students create a mental model of a specific knowledge entity in their minds. A person's cognitive processes operate on such mental models, are based on logic-like rules of inference, and are understood to happen solely in the person's mind. Constructivism extends this cognitive perspective and suggests that it is not possible to transmit knowledge in instructions and by memorizing facts or information. Instead, students must construct knowledge which means that they must connect and interrelate new information and experiences with their existing understanding. Piaget described this ongoing knowledge construction as the cognitive processes of assimilation and accommodation [21]. Therefore, learning is regarded as being a highly self-directed and active process where students' pre-knowledge and motivation are crucial factors. Consequently, the teacher's role is to arrange a learning environment that engages students in knowledge construction by incorporating their pre-knowledge and stimulating their interest and motivation to interact with new issues, problems, or information ([27], p. 348).

Like cognitive approaches, constructivism has been criticized for focusing only on the single student and solely on cognitive processes, neglecting the social and cultural environment in which students' learning takes place. Inspired by Vygostky's psychology, a variety of approaches with a very different understanding of learning emerged, such as situated learning, socio-cultural theory, social constructivism, or situated cognition theory [23]. Based on these approaches, several studies were conducted in the last thirty years, see for example [14], [18], [24], which have provided new insights into what we know about learning. Because of space limitations, we will only summarize the key characteristics of this family of approaches, focusing mostly on situated cognition theory introduced by Brown et al. [2].

The approaches have in common that cognitive processes are viewed as inseparable from a person's activities, the socially and culturally shaped environment in which these activities happen, and the tools (physical or symbolic) a person uses to accomplish them. Domain knowledge, no matter if of declarative, procedural, or conditional nature, is understood to always be contextualized within the situation in which it was developed, representing specific meaning that is "inherited from the context of use" ([2], p. 33). Brown et al. understand domain knowledge as a specific conceptual or mental tool and argue that learning how to use knowledge as a tool "involves far more than can be accounted for in any set of explicit rules. The occasions and conditions for use arise directly out of the context of activities of each community that uses the tool, framed by the way members of that community see the world. The community and its viewpoint, quite as much as the tool itself, determine how a tool is used. [...] Just as carpenters and cabinet makers use chisels differently, so physicists and engineers use mathematical formulae differently." ([2], p. 33).

From the situated cognition perspective students succeed when their learning process is situated, which means that the situation in which domain knowledge is taught corresponds to the situation in which it was developed and is still used. Collins et al. [3] draw on research investigations by Lave [14] and argue that for the longest time in human history, the natural form of learning was apprenticeship: a master-student relationship that focuses on practicing contextualized knowledge and skills in authentic situations which provide meaning to the activities involved. Learning was not only a form of "acquiring" knowledge and developing skills to handle it but also a form of enculturation into a certain community. Being set in a specific workplace, tasks and problems arose not from pedagogical concerns but from the demands of the authentic environment ([3], p. 48ff). Additionally, in the workspace of traditional apprenticeship, reasons for specific activities are much better understood than in formal schooling: students "are motivated to work and to learn the subcomponents of the task, because [...] they have seen the expert's model of the finished product, and so the subcomponents of the task make sense. But in school, teachers are working with a curriculum centered around reading, writing, science, math, history, etc. that is, in large part, divorced from what students and most adults do in their lives." ([3], p. 50).

With regard to situated cognition theory, Collins et al. argue that typical forms of formal schooling are the opposite of a situated learning environment ([3], p. 47ff). In science classes, students traditionally are supposed to acquire specific declarative and procedural knowledge, which is mostly introduced and demonstrated as a stand-alone generalized product, which is therefore decontextualized from the situated activities in which this knowledge was once developed. Cut off from the uncounted observations, experiments, as well as related problems and questions, it is very difficult for students to reconstruct the meaning and relevance of science knowledge in the scientific community. As a consequence, conditional knowledge remains tacit since a specific context is not emphasized. From this point of view, it makes a lot of sense why students have deficiencies in the acquisition and application of scientific knowledge and its conceptual understanding as well as why they lose interest and motivation for science.

2.2 Key Characteristics of ChiK

In order to address the problems of science education in formal schooling, German science education changed significantly in the last decade. The traditional objective of students acquiring a large body of declarative and procedural knowledge has been abandoned. Instead students are supposed to develop scientific literacy that is defined by educational standards for science education, which were approved in 2004 by the Kultusministerkonferenz (German national board of education) [1]. These standards reflect the constructive and situated view on learning and consist of four major competency areas, with proficient use of domain-specific knowledge being one of them. For chemistry education, the later is defined by six basic concepts, e.g. *donor-acceptor reactions*, that represent the essence of what students should know about chemical domain knowledge ([16], p. 1442).

In order to facilitate students' development of scientific literacy, ChiK aims to offer a learning environment that corresponds to the constructive and situated view on learning and which incorporates the learning outcomes defined by the standards. For this reason, each teaching unit and its topics are composed of a specific context. The latter exemplifies one or several basic concepts by concrete topics and relates them to authentic situations, problems, or tasks. The idea is for students to work with many different contexts but to decontextualize the contexts' topics to the same six basic concepts ([16], p. 16). This way, students are expected to achieve both: understanding the general abstract nature of the basic concepts as well as their contextualization in a number of different situations. The concrete teaching unit is supposed to address students' preknowledge and to create tasks that leave students the possibility of interacting actively and in a self-directed way with the context and its topics developing the specific competencies defined within the standards. In addition, the contextualization reflects the concepts' relevance and meaning and therefore makes it easier to enhance students' interest and motivation for the learning process. For this reason, different student-oriented teaching and learning methods are used with regard to the constructive view of learning. In summary, a context serves as the teaching unit's content, as well as an environment for situated development and application of knowledge and competencies [19].

3 The Context-based Approach IniK

IniK as a pedagogical approach for lower secondary computing education has been discussed in the past ten years by many different authors, see [4], [8], [12], [20], for a detailed historical reconstruction of context-based and application-orientated approaches of CS Education, see [7]. In this article, we focus our discussion on the recently suggested approach by Koubek et al. [12], see also [5] and [26]. In the next two subsections, we will introduce IniK by describing the approach's historical roots, general objectives, as well as its key characteristics.

3.1 Historical Roots and Objectives

IniK is conceptualized with regard to the context-based teaching approaches developed for science education, especially on the ChiK approach (see subsection 2.2). On the other hand, IniK also stands in the tradition of former pedagogical approaches of secondary computing education. CS was introduced in the 1970s as a non-mandatory subject in secondary schools in Germany (for a detailed introduction into the German secondary school system and the current situation of CS as a school subject, see [15]) followed by several pedagogical approaches among which the algorithm- and application-based approaches, developed in the 1980s, were particularly prominent.

The algorithm-based approach focused on algorithms, programming, and the idea that computer systems can only be understood by the students when the latter can design and implement their own programs. But only a minority of students who were very motivated and interested managed to accomplish this ambitious educational goal. Although being highly demanding learning objectives, the programming taught in CS class remained focused on rather simple and small-sized algorithms and programs without being directly connected to CS systems used and applied in specific domains outside school. It was criticized that such topics taught in CS class are highly sophisticated, relevant only for experts, and did not reflect general education to such a point that the subject's removal from lower secondary schooling was discussed. Being just a supplementary subject, the objective was to elaborate a new approach that could overcome this problem and therefore legitimate the existence of the subject in secondary schools.

The application-oriented approach suggested that topics taught in CS classes should be applicable and useful outside school, which would engage students more than specific programming skills. In order to emphasize the relevance of CS, the application-based approach argued for focusing on specific applications and discussing and analyzing them from different perspectives. This ambitious approach mostly failed because of several reasons such as unsatisfactory teacher training, which continue to be focused on programming. In the early 1990s, the approach lost its focus on computing literacy and was turned into a one semester ICT-class where students were instructed to learn how to use common applications like word processing, spread sheets, and data bases [7]. A longer debate started about how computing education could be legitimated for lower secondary schooling, focusing on the clarification about what is meant by computing literacy (informatische Bildung).

Because the Kultusministerkonferenz (German national board of education) did not define educational standards for CS, Puhlmann et al. suggested educational CS standards which are supposed to reflect computing literacy, see [22]. These standards consist of two major competency areas students are supposed to develop during lower secondary schooling. As Stechert points out, this work only in part follows the same structure as the standards for science education. Instead, it describes educational objectives or goals students should achieve by the end of a specific grade ([25], p. 104-110). In addition, the definition of the competencies was done in a normatively process without being theoretically developed and empirically evaluated. But this work consolidates the different debates about what should be taught in CS class in lower secondary schools.

IniK incorporates the standards by Puhlmann et al. and aims to offer teaching units that permit students the opportunity to develop computing literacy. Like the application-based approach before, IniK aims to outline the subject's relevance by outlining the subject's relevance in students' everyday lives. This objective goes back to a problem-based teaching approach that focuses on real problems and authentic environments and situations that are supposed to enhance student interest for CS, and therefore motivate students to learn more about the problem as well as the skills, knowledge or tools needed for its solution ([5], p. 97ff).

3.2 Key Characteristics of IniK

With regard to the context-based teaching approaches from science education, Koubek et al. define three major principles IniK teaching units should incorporate ([12], p. 24ff). In particular, they should be:

1. orientated towards a context
2. linked to educational standards for CS
3. designed to use diverse teaching and learning methods

For the first principle the authors suggest that topics covered in class should be part of and derived from students' everyday life contexts. Koubek et al. define context as a set of different dimensions of certain situations that students can experience. These dimensions can be, e.g., technology, social and ethical aspects, law, or economy. Therefore, the decontextualization is done towards these different dimensions ([5], p. 100). The chosen context must be part of students' life world and be visible during the whole teaching unit. The breath of possible topics covered by one context is supposed to outline how CS is connected to other fields and therefore outline the discipline's relevance in students' everyday lives: "a context must be understood as a set of meaningful topics or questions that students interpret as being connected and coherent to each other and that guide students' activities" ([12], p. 25) (original quotes in German were translated by the authors of this article). Diethelm et al. discuss further criteria for a context with regard to the definitions used for ChiK ([5], p. 102).As examples for a context Koubek et al. suggest: e-mails, mobile phones, social networks, or file-sharing, see [26].

For the second principle, the authors suggest that the chosen context's underlying topics should be aligned with the educational standards of CS suggested by Puhlmann et al. [22]. This work consists of two major competency areas (p. 11ff). The first one is focused on content specific competencies and subdivided into: information and data; algorithms; languages and automata; information systems; informatics, people, and society. The second area is focused on process-specific competencies and subdivided into: modeling and implementing; arguing and evaluating; structuring and networking; communicating and cooperating; presenting and interpreting. Each subfield contains a detailed description of what students are expected to know and be able to accomplish by the end of a certain grade. For example: "Students know algorithms for solving tasks and problems from different domains (content competency "algorithms"). [...] They implement models with adequate tools and reflect the models and their implementation (process competency "modeling and implementing")." (p. 13). According to Koubek et al., IniK-based teaching units are expected to be aligned with the competencies described by the standards and to give students the possibility to accomplish the specified learning outcomes (p. 27). In the long term, the objective is to develop a variety of IniK-based teaching units that cover all learning outcomes described in the standards.

For the third IniK principle, Koubek et al. suggest using a variety of teaching methods like the ChiK approach. As an example of a teaching unit see "e-mail for you (only?)" by Gramm et al. [9] that focuses on the question of how private communication is technically realized with computer networks.

4 Discussion

In this section, we will discuss the IniK-approach introduced in the previous section with regard to the theoretical framework of ChiK.

4.1 Missing Basic Concepts

Like ChiK and the other context-based approaches from science education, IniK teaching units offer contextualized topics that are taken from students' everyday life situations. Although IniK incorporates the same idea of contextualization, the objective behind is very different. The contextualization of CS topics is supposed to emphasize that the topics in CS class are useful and relevant for the students. The different dimensions of a context shall demonstrate the broadness of CS and the variety of different contexts CS systems are connected and interrelated with. In particular, this means that the decontextualization is supposed to be done towards different dimensions that are related to different domains, see ([5], p. 100). This way, students are supposed to learn that CS topics are not only limited to a system's technical aspects or to sophisticated topics like programming. In consequence, the demonstrated broadness of CS might legitimate the subject better than former computing approaches.

IniK's emphasis on the relevance of CS in students' everyday life is very important, but in our opinion, it neglects the constructive and situated perspective on learning the context-based approaches from science education all focus on. As outlined in subsection 2.1, ChiK's objective is to provide a learning environment where students can develop scientific literacy, defined by the four competency areas specified in the educational standards for science education. The chemical knowledge that these competencies refer to is defined by six basic concepts. The situated cognition theory approach emphasizes the problem that decontextualized, abstract knowledge is difficult to learn because it does not reflect the natural form in which humans easily acquire skills and understanding. ChiK responds to this problem by focusing on basic concepts that are contextualized with problems or tasks from authentic situations. Instead of teaching a huge body of chemical domain knowledge, ChiK's objective is to enable students to understand the basic concepts in general and to experience them in many different contexts. ChiK's core idea is to decontextualize a context's topics to the same basic concepts over and over again making the difference between abstract and situated chemical knowledge "visible" for the students. This way, students are supposed to develop domain-specific competencies that enable them to apply these concepts in many different situations and be also able to construct a general understanding of them.

Without basic concepts (or something similar that captures domain knowledge of CS) and the decontextualization towards them, criteria for choosing the adequate CS topics and appropriate contexts are missing for IniK teaching units. For example, the CS topics covered by teaching unit "e-mail for you (only?)" are protocols (SMTP and POP3) and cryptology (RSA algorithm), see [9]. The unit aims to foster competencies from the subareas: information systems; informatics, people, and society; arguing and evaluating. The technical realization of communication with e-mails, possible pitfalls as well as protocols and cryptology are important CS topics, but without decontextualization to specific CS concepts or principles it remains unclear how these topics contribute to the defined learning outcomes in the educational standards for CS. The second principle of IniK, the alignment between a context and the educational standards, is not an equivalent substitute for the decontextualization towards basic concepts. The standards are meant to describe competencies. Basic concepts are domain-specific knowledge entities that students are supposed to understand and be able to handle with regard to the specified competencies.

So far no basic CS concepts or principles have been defined for CS education. Of course, the educational computing standards implicitly include domain-specific knowledge, specially the content specific parts (information and data; algorithms; languages and automata; information systems; informatics, people, and society). But, the way the standards are defined expresses the skills and abilities students are supposed to develop, while a clear definition of basic concepts the standards implicitly refer to is missing. Take for example, the following competency: "students know algorithms for solving tasks and problems from different domains" ([22], p. 13). This description refers to a general, abstract understanding of algorithms including the ability to apply this in specific domains. It seems that an IniK teaching unit that fosters this competency must do both: present a concrete algorithm from a specific domain as well as decontextualize it towards a general understanding of algorithms, so that students not only learn to know and apply the one presented algorithm but also develop a general understanding of algorithms and the ability to reapply this in different domains. For this matter, basic concepts or principles as well as the decontextualizaion towards them are needed.

It might be that there is no reason to address the difference between abstract and situated CS knowledge, since this is a problem that students have in science education but not necessarily in CS education. It might be that students will develop the competencies described in the educational CS standards without explicit decontextualization towards basic concepts. But then, it should be discussed further why IniK is conceptualized with regard to a specific pedagogical approach without incorporating its key objective. This is an important issue because when IniK's objectives are different at this point, another pedagogical approach might be more suitable than the adapted context-based approaches from science education, see for example [20].

4.2 Student Interest and Mental Models

As outlined in section 2.2, context-based approaches in science education incorporate the constructivist understanding of learning which means that topics students have to learn should emphasize certain meaningfulness that is connected to students' preknowledge. From this point of view, the contextualization of a basic concept provides its different possible relevance and makes it more understandable to the students why they are supposed to learn and work with it. As a consequence, the context-based learning environment is supposed to enhance students' interest and motivation for the specific science topics [16].

IniK on the other hand has the objective of working with topics that are already meaningful and relevant for the students. By choosing contexts that students are familiar with (like e-mails or file sharing) IniK authors assume that students are interested in these contexts and curious to learn more about them (see [4], p. 69). Still, we doubt that this assumed causality is always the case. Each of us is surrounded by technology, but this has not always had an impact on our interest. For example, just because a person uses an elevator every day does not mean that he or she is interested to know how it functions (technical dimension), how much it costs (economical dimension), or when the first elevator was developed (historical dimension). For example, Knobelsdorf investigated students' computer usage as part of students' biographies, see [11]. The investigated biographies show very clearly that in the course of their computer usage not all students developed interest for CS and competencies to interact with the computer in a proficient way, although being similarly exposed to computers (p. 135ff). According to social constructivism, interest and relevance are a person's (or a group's) subjective constructions of meaning. The later depends on what a person experiences in her or his life and with whom the person is interacting. Becoming interested in a new field depends on how much it provides connection and coherence to previous experiences, see [13]. Therefore, a context students are familiar with can have the potential to create interest. But for the latter, knowledge about students' background and previously made experiences as well as what students expect from the CS course are needed. Proposing a context that was chosen with regard to how much it is aligned with students everyday life will not automatically enhance students' interest to the different domains IniK teaching units refer to.

So far, many of the suggested contexts for IniK teaching units are focusing on specific IT devises (like mobile phones and internet) and applications (e.g., e-mails) that students know from everyday use, see [26]. We posit that most students are not particularily interested in the functionality of these devices since the IT industry teaches end-users that they do not need any kind of computing literacy in order to use their products. Being treated as useful tools for specific objectives on can accomplish with, this argument is also supported in the technology reflections by Heidegger who argues that people think through a tool as long as they can carry out goals with it. Heidegger argues that people start to think about the tool itself when there is breakdown in work using it ([10], p. 3-35). Therefore, besides proposing a device or object and its specific context, breakdowns could be a very good starting point for students to create awareness that they need to know more than just the interface in order to use such devices skillfully. Incidentally, the above quoted teaching unit "e-mail for you" is simulating that someone else is abusing the students' e-mail addresses. This breakdown in students' familiar usage habits with e-mails makes them understand the importance of safe protocols and message encoding. Hence, we posit that student interest for CS will be more enhanced by breakdowns in the interaction with a certain device they are familiar with than just by presenting the device as part of a familiar context.

Focusing on breakdowns also incorporates another important aspect that so far is not addressed by IniK though highly emphasized within PiK, the context-based approach in physics education: the question of students' pre-understanding [6]. Norman [17] suggests that people often run into problems of use of technical devises or artifacts when their mental models about the artifacts functionality are incorrect. According to Norman, such mental models are developed by user interaction at the interface of the artifact. Based on the actions that they are able to take and the effects that are visible, a person makes inferences about the causal mechanisms that connect actions to effects. Focusing on students' mental models about devises' or applications' functionality could better emphasize the constructive nature of CS artifacts and might represent a more adequate pedagogical approach for computing education, than just the context-orientation from science education.

5 Conclusion

In this paper, we discussed the context-based approach IniK. This approach is based on context-based approaches from science education that are a serious attempt to combine formal education with a constructive and situated view on learning. Comparing IniK with ChiK, the context-based approach from chemistry education, we showed that the approaches do not coincides on the question of decontextualization and student interest. What is a real strength of IniK is that it addresses situated learning and the student perspective. But, without the decontextualization towards the same basic CS concepts, IniK risks producing a set of teaching units where the chosen domain knowledge remains rather arbitrary and misses a clear connection to computing literacy. The contextualization of CS topics will not necessarily enhance students' interest for CS. More insights are needed about students' background, how they experience CS artifacts in their everyday lives, and what is therefore relevant for them. Addressing these problems and suggesting possible directions for how the approach could be improved further, this paper is a contribution to the ongoing discussion about the IniK approach and computing literacy.

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