Assignments in Computer Science Education: Results of an Analysis of Textbooks, Curricula and other Resources

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Abstract: In this paper we describe the recent state of our research project concerning computer science teachers' knowledge on students' cognition. We did a comprehensive analysis of textbooks, curricula and other resources, which give teachers guidance to formulate assignments. In comparison to other subjects there are only a few concepts and strategies taught to prospective computer science teachers in university. We summarize them and given an overview on our empirical approach to measure this knowledge.

Keywords: Pedagogical content knowledge, computer science teachers, students' knowledge, students' conceptions

1 Introduction

The formulation and preparation of assessments is an everyday task for a teacher. As it involves a deeper knowledge of the specific topic and an understanding for students' cognition it can be classified as a part of the pedagogical content knowledge (PCK) defined by Shulman (1986).

The competency to choose, design and prepare questions and tasks for assessment and practice is part of many content-specific definitions of the PCK. In the COACTIV project the pedagogical content knowledge of mathematics teachers was tested. One of the main categories is "Tasks": "When appropriately selected and implemented, mathematical tasks lay the foundations for students' construction of knowledge and represent powerful learning opportunities" (Krauss, Baumert, Blum, 2008). The importance of this category is supported by other research projects as well (Riese et al., 2013). Of course, this can also be applied to didactical computer-science courses in university. An analysis of German university curricula for computer science education has shown that only a minority of them includes the design of tasks and preparation of assessment. Meanwhile there is a broad focus on the actual process to solve tasks (especially problem-solving).

Our experiences in teachers' training in computer science education show, that there are deficiencies in the knowledge of assessment preparation and creation. Students know about general methods and concepts like didactical models and learning software or resources. But they often fail to transfer these in order to fulfill their own needs. At times they have problems to evaluate the applicability of concepts (i.e. the use of a role play with senior class students). Nevertheless they have to do this in their teaching traineeship at the latest. This leads to the question when and how computer science teachers learn to develop assignments.

2 Related Work

Research and also general concepts for the creation and formulation of tasks in computer science education are rare. To substantiate this assertion we also analyzed textbooks used in content-specific didactical courses in mathematics and physics at German universities. These often outline and exemplify criteria to evaluate tasks, methods to create an appropriate context and other instructing information (e.g. (Kircher, Girwidz, Häußler, 2009), (Reiss, Hammer, 2010)). In contrast these are rare and less comprehensive in computer science education literature. However the relevance of this competency is undeniable, since it is mentioned in several scientific papers. For instance Hubwieser et al. (2013) developed a literature-based category system for PCK containing the topic "tasks and assignments" as part of the category "Specific teaching elements".

Ragonis et al. (2010) focus on the development and implementation of computer science teacher preparation programs. They did a survey with heads of these and present a list of main characteristics of computer science education, which should be understood by teachers. One of these are "[...] strategies to evaluate pupils' products: class assignments, homework, exams, projects" as a topic which should be understood by prospective computer science teachers.

Hazzan et al. (2011) emphasize the need of teachers' knowledge about assignments: "It is important, however, that computer science teachers be aware of the fact that additional types of questions exist." They introduce three steps for the preparation process of questions in computer science classes: Planning, Solving and Estimation of the needed time to solve the question. These involve different specific sub-topics and basic principles. Furthermore they give an overview of types of questions in terms of 12 individual concepts and illustrate the possibility to join them. They extend this by three different kinds of questions: story questions, closed questions and unsolved problems, and consider the possibility to combine these. A successful design of assessments is only possible with a reliable estimation of the difficulty level. Thompson et al. (2008) present the approach to evaluate this for programming tasks by the use of Bloom's taxonomy. Although this refers to programming only, it is presumable that an adaption to other contents is feasible.

Schlüter (2008) evaluates the difficulty of task through ten criteria: redundancy, level of formalization, closeness to the world of experience, level of abstraction, complexity, cognitive level, type of knowledge, area of content and processes (according to the German Gesellschaft für Informatik Standards (2008)) and the area of requirement.

The Bebras contest is a computer science contest for students. It is conducted in several countries. The tasks are prepared by "The Bebras International Tasks Workshop" where experts from every participating country suggest tasks and discuss them (2013). In the context of the Bebras contest (resp. the German contest "Informatik-Biber") the creation and evaluation of tasks has been documented in several papers. The basic goal of the contest is to encourage students for the field of computer science and to give them a deeper understanding of how modern information technology works (Dagiene, 2008). Thus it differs from tasks used in school environments, which are meant to support a students' learning processes and for assessment later on. Nevertheless the Bebras goals are relevant for them as well as they require similar criteria for their applicability. For instance these are the time needed to answer, an adequate difficulty level and are easily understandable (Dagiene, Fuschek, 2008). Although these are documented and described very well, they cannot be measured easily. Pohl & Hein (2013) point out that the experience gained from the improvement process of single challenge tasks can be transferred to other tasks as well. Additionally they might lead to general practices, which help to assure the quality of computer science tasks.

The selection of research and practical results presented above gives an insight into the current state of research. It is unquestionable that there are numerous research approaches. Nevertheless these are apparently rarely connected. Moreover in comparison to other subjects general and fundamental concepts are missing. We are planning an empirical survey in order to retrieve results on the actual development of competencies in the field of assessment development. These are part of a research project on the development on teachers' knowledge about student's conceptions and cognition.

3 Research Method

In our project we aim to measure teachers' competencies in students' knowledge and conceptions. To classify the fields of knowledge we adopted two categories for out test items from the COACTIV project, which are PCK student and PCK task. PCK student describes the analysis and prediction of typical students' errors or misconceptions. The focus of PCK task is the knowledge of how a student answers a task. We extend the definition of the latter with the competency to create proper task, i.e. the formulation of questions for expected answers. The test will be conducted with computer science teacher trainees and teachers. We have developed a first set of test-items, which was used for a survey in December 2013. This gave us first insights on the applicability of the items.

In this article we focus on a test item of the category PCK task, which pays attention to elementary aspects for the formulation of assignments: the knowledge of how to formulate tasks and the knowledge of how a student will answer them (Ohrndorf, 2013). The latter also involves an imagination of different approaches, which will be explained in the following example test item.

Example task: In the field of cryptology, the fundamentals of symmetric key encryption were introduced to an 8th class. As their homework your students answer the following textbook task:

> *"You want to exchange hand-written messages with your classmate. How can you assure that he or she is the only one who is able to read the message? Describe your approach in detail."*

"Please describe at least two possible answers your students could give."

It's obvious that this task allows a number of answers. We confine ourselves to three examples, which were given by university students attending computer science didactical courses:

1. We first agree on an encryption code. This can be a number from 1 to 26. When we write a message every letter is represented by a number: a = 1, b = 2, c = 3... To encrypt a text every letter is replaced by adding the code to the number to get the secret letter. When we use 9 "a" would become "j" and "b" would become "k".

2. We implement a transposition cipher by creating a unique pattern, which describes the way the message can be read when encrypted. This can be a spiral starting in the middle and rising anti-clockwise. The encrypted text must then be written in this scheme to read the message.
3. We both download a tool that allows encrypting text with a complex encryption method and agreeing on a common key. To exchange the encrypted messages we can print them or write them down.

These answers give an idea of different approaches and methods. As they are basically right or follow a right approach, they do not fulfill further demands on the understanding of students' cognition. Answer 1 explains the use of a classical Caesar cipher, which is often taught in the introduction of encryption techniques. Answer 2 uses a transposition cipher (route cipher). This allows a more secure encryption, but might be too ambitious for an 8^{th} grade student. Answer 3 actually circumvents the specified encryption of hand-written messages by typewriting it and using available software. This is undoubtedly the weakest answer since it describes an application-oriented solution without any usage of actual computer science knowledge or curricula knowledge.

4 Conclusion and Future Work

As described above one of the main challenges in the project is the adequate rating of the teachers' answers. Answers might be right from a technical view, but are not satisfying concerning their relevance and applicability in lessons. Due to this, the answers cannot be scored by a simple rating, which defines right and wrong. Therefore a specific rating procedure has to be defined for every test item, where the ambitions and goals are considered.

We have just done a preliminary assessment in December 2013 and are evaluating the results. This will help us to develop the main survey, which will be conducted at the end of 2014.

References

Dagiene, V. (2008). The bebras contest on informatics and computer literacy-students' drive to science education. In *Joint Open and Working IFIP Conference. ICT and Learning for the Next Generation* (pp. 214–223). Kuala Lumpur.

Dagienė, V., Futschek, G. (2008). Bebras international contest on informatics and computer literacy: Criteria for good tasks. In *Lecture Notes in Computer Science* (pp. 19–30). Berlin Heidelberg: Springer.

Gesellschaft für Informatik e.V.: *Grundsätze und Standards für die Informatik in der Schule*. LOGIN-Verlag, Berlin, Arbeitskreis „Bildungsstandards" der GI. 2008. URL: http://bebras.org/about/ (07.11.2013).

Hazzan, O., Lapidot, T., Ragonis, N. (2011). *Guide to Teaching Computer Science – An Activity-Based Approach*. London: Springer.

Hubwieser, P., Berges, M., Magenheim, J., Schaper, N., Bröker, K., Margaritis, M., Schubert, S., Ohrndorf, L. (2013). Pedagogical Content Knowledge for Computer Science in German Teacher Education Curricula. In *WiPSCE '13, Proceedings of the 8th Workshop in Primary and Secondary Computing Education*. Aarhus.

Kircher, E., Girwidz, R., Häußler, P. (2009). *Physikdidaktik*. Berlin, Heidelberg: Springer Berlin Heidelberg. doi:10.1007/978-3-662-22299-7

Krauss, S., Baumert, J., Blum, W. (2008). Secondary mathematics teachers' pedagogical content knowledge and content knowledge: validation of the COACTIV constructs. *ZDM*, 40(5), pp. 873–892.

Ohrndorf, Laura (2013). A taxonomy of errors for computer science education. In *World Congress on Computers in Education (WCCE)*, Torun.

Pohl, W., Hein, H.-W. (2013). Aufgabenqualität im Informatik-Biber. In Breier, N., Stechert, P., Wilke, T. (Eds.), *INFOS 2013, 15.GI-Fachtagung „Informatik und Schule" Praxisband* (pp. 51–58). Kiel.

Ragonis, N., Hazzan, O., Gal-Ezer, J. (2010). A survey of computer science teacher preparation programs in Israel tells us: computer science deserves a designated high school teacher preparation, *Symposium on Computer science*, pp. 401–405.

Reiss, K., Hammer, C. (2010). *Grundlagen der Mathematikdidaktik* (p. 147). Birkhäuser.

Riese, J., Borowski, A., Fischer, H., Gramzow, Y., Kulgemeyer, C., Reinhold, P., Schecker, H., Tomczyszyn, E., Walzer, M. (2013). Professional knowledge of physics student teachers – ProfiLe-P. In Blömeke, S., Zlatkin-Troitschanskaia, O. (Hrsg.), *KoKoHs Working Papers*, 3. Berlin, Mainz: Humboldt-Universität & Johannes Gutenberg-Universität.

Saeli, M., Perrenet, J. (2011). Teaching programming in secondary school: a pedagogical content knowledge perspective. *Informatics in Education*, 10(1), pp. 73–88.

Schlüter, K. (2008). Je schwieriger die Aufgabe, desto klüger der Kopf? In *Didaktik der Informatik - Aktuelle Forschungsergebnisse* - 5. Workshop der GI-Fachgruppe „Didaktik der Informatik" (pp. 77–86). Bonn: Köllen.

Shulman, L. (1986). Those who understand: Knowledge growth in teaching. *Educational researcher*, 15(2), pp. 4–14.

Thompson, E., Grove, H., Luxtonreilly, A., Whalley, J. L., Robbins, P. (2008). Bloom's taxonomy for CS assessment. In *Proceedings of the Tenth Australasian Computing Education Conference (ACE2008)*, pp. 155–162.

Biography

Laura Ohrndorf received her diploma in computer science (2011) from the University Duisburg-Essen, Germany. Since July 2011 is a research assistant at the University of Siegen. Her main research interests concern misconceptions in computer science education and their identification.