Undergraduate Teaching Assistants in Computer Science

Teaching-Related Beliefs, Tasks, and Competences

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Abstract—We report on the first steps of KETTI, a project that aims towards the development of a competence model for undergraduate teaching assistants (UTAs) in computer science. Using qualitative methods, we obtained a classification of existing designs for teaching that employ UTAs; some of the observed factors directly influence the methodological decision space of UTAs. We developed and implemented a UTA training scheme designed to foster student-oriented teaching in recitation sessions along with an instrument to gauge the effects of this instruction on a variety of psychometric scales. We report results from a small-scale pilot study at three institutions showing positive effects on teaching-related beliefs and self-efficacy.

Keywords—Undergraduate Teaching Assistants, Computer Science, Competence Model, Pedagogical Content Knowledge

I. INTRODUCTION

Employing undergraduate teaching assistants (UTAs) in computer science labs and recitation sessions has a long tradition in various countries. Several computer science departments have developed at least semi-formal programs to prepare UTAs for their job, e.g., [1], [2], [3], [4]. In addition to helping to cope with an increasing number of students and to offer more or smaller recitation sessions, UTAs have been attributed with positive influences on the retention of students [5]. Also, a larger group of “instructors” inevitably leads to a more diverse spectrum of potential tutors which may serve as role models for different groups of the student population. This is highly relevant as the time spent in recitation sessions or labs makes up a non-trivial part of a student’s contact time with instructors, especially in courses where lecture attendance is not required, e.g., because of online self-study resources. In the light of this, it is surprising that UTA training has received comparatively little attention in the computer science education community so far. Patitsas [6] points out that general education literature and anecdotal evidence alike suggest that there is still room for improvement when it comes to (U)TA training.

In the following, we describe the first steps towards understanding the dimensions influencing possible improvement strategies. To make our research as broadly applicable as possible, we focused on first-year CS courses which, seen as a whole, are fairly standardized across schools and countries.

II. PROJECT DESCRIPTION

The KETTI-project is a research cluster focused on developing a competence model for undergraduate teaching assistants in computer science along with corresponding instruments. In addition, training modules aligned with the desired competences will be developed and made available for academic use. KETTI is funded by the German Federal Ministry of Education and Research and brings together researchers from computer science education, computer science, and psychology. The core of the project consists of four research groups at three large public German research universities (Technical University of Munich, Westfälische Wilhelms-Universität Münster, and University of Paderborn). These universities cover a broad range of students audiences due to different intake policies (limited/unlimited/voluntary proficiency test). All CS departments have offered formal UTA training in the past.

To broaden the scope even further, KETTI includes six associated partners at five other CS departments at German universities; these department have not established formal UTA training, yet. The partners are consulted periodically to ensure that assumptions about student and UTA populations are not biased towards the departments with a tradition of UTA training. Two additional partners at mathematics departments are consulted to enable transfer of knowledge between disciplines and to contrast general requirements and CS-specific requirements.
Throughout the project, we used the following working definition: “Recitation sessions are sessions that are run by non-independent instructors and that are administratively linked to a course which determines the topics covered.” All participating instructors agreed that this definition faithfully captured the nature of their recitation sessions.

III. RELATED RESEARCH

It has long been established that practical teaching experience alone is less effective than even a short teaching-related training, see, e.g., Dalgaard [7]. Consequently, training programs for (U)TAs have been implemented for a substantial period of time—see Weimer et al. [8] for an overview of aspects considered when designing such programs.

Abbott et al. [9] review early research on (U)TA training. According to their findings, most of the early training formats rely on student ratings and pre/post video analyses of recitation sessions. Andrews [10] performed a small-scale study focusing on matching instructional and learning styles.

Graduate TAs are outside the focus of our study, but some aspects of their duties investigated in previous studies, e.g., classroom management [11], can also be relevant for UTAs.

Peer tutoring has been shown to positively influence both academic performance [12] and retention [13]. Given increasing enrollment numbers, however, the costs of maintaining such tutor-to-student ratios appear prohibitive.

Patitsas [6] considered environmental factors influencing the job satisfaction of teaching assistants and considered professional development of UTAs teaching in pairs [14].

IV. METHODOLOGY AND RESULTS

The focus of the first phase of the project was to gather data leading to an understanding of the teaching/learning designs used in first-year computer science courses at the participating institutions. In particular, we started to develop a competence model for UTAs in computer science. Such a model can be used as the basis of a rigorous design of formal UTA training courses as well as for an empirical evaluation of both the training and the UTAs’ teaching.

For this, the following analyses were carried out:

1) Identification of dimensions of a UTA competence model;
2) Identification of tasks assigned to and roles assumed by UTAs;
3) Identification of teaching-related beliefs.

We then developed a corresponding training methodology along with an instrument to measure the effectiveness of training.

In particular, to delineate the decision space of UTAs and, hence, to understand the limits of what can be expected from them, we explored the prevailing conditions of the teaching environments, teaching beliefs, and the perceived and observed roles of both the instructors and the (undergraduate) teaching assistants. Knowing these conditions will also facilitate implementing the UTA training courses at participating institutions. Given the short period of time usually available for UTA training [8], knowing such (possibly site-specific) predispositions is needed to ensure its effectiveness and suitability.

A. Dimensions of a UTA Competence Model

Although UTAs are not expected to be educational professionals, their role is to a large extent correlated with teaching and students’ learning. Therefore, a competence model for UTAs should consider models of teachers’ professional competence as well as empirical findings on the educational practice and the attitudes of UTAs.

The professional competence of teachers is known to be a multidimensional construct. The discussion on the professionalization of teachers was highly influenced by Shulman’s concept of the structure of teachers’ knowledge [15]. The main categories of Shulman’s approach were general pedagogical knowledge (PK), content knowledge (CK), and pedagogical content knowledge (PCK).

Several empirical studies and discussions and derived concept enhancements of the professional competence of teachers refer to this model—see, e.g., [16]. With regard to PK in mathematics, the COACTIV competence model differentiates between: “Knowledge of the didactic and diagnostic potential of tasks [...]; Knowledge of student cognitions (misconceptions, typical errors, strategies) and ways of assessing student knowledge and comprehension processes; Knowledge of explanations and multiple representations.” [16, p. 33].

Other cognitive aspects of the provided competence model are counseling and organizational knowledge. According to Weinert [17], the COACTIV model of teachers’ professional competence also contains non-cognitive competence dimensions like ‘beliefs, values, and goals’, ‘motivational orientations’ and ‘self-regulation’ with sub-categories like ‘control beliefs and self-efficacy beliefs’ and ‘teacher enthusiasm’.

The KUI competence model on CS teachers’ professional competence [18] also considered competence dimensions regarding different fields of pedagogical activities such as ‘preparation of lessons’, ‘intervention strategies’ and the ability to evaluate and reflect the conducted lesson. The theoretically derived dimensions of this study cover only a part of the competence model and are mainly focused on the organizational context of the UTAs’ teaching activities, their attitudes and beliefs. The main categories are:

Attitudes & Motivational Orientation Self-concept and understanding of one’s role as a UTA / relation to the students; Previous teaching experience, e.g., in extraschool tutoring; Motivation to work as a UTA; Reasons for enrolling in computer science.

Subject Matter & Learning Objectives Subject matter and learning objectives of the course assigned to.

Teaching-related Tasks as a UTA Preparation of the recitation session; Educational intervention strategies
during the course; Assessment and reflection of session
time; Assessment and reflection of session
classifying one’s own role as a UTA; Demanding
aspects when acting as a UTA, e.g., heterogeneity of the
course participants, PCK-aspects of a subject.

**Organizational Structure**
Assigned tasks of the (U)TAs in
the context of a lecture and division of roles between
instructor and (U)TAs; Information and
communication structure between instructor and
(U)TAs; Organizational knowledge and reflection of a
UTAs role within the academic teaching activities, e.g.,
division of labor, task assignments, or responsibilities.

Based on these empirically founded and theoretical
cornerstones, we developed guidelines for semi-structured
interviews with UTAs. We additionally developed similar
guidelines for interviews with course instructors and head
teaching assistants (HTAs) to get a more complete picture.

The interviews addressed motivational and curricular
aspects as well as structural conditions of teaching and learning.
The focus of the interviews was to obtain information about
attitudes, motivation, working conditions, and perceived
educational practice. We were especially interested in eliciting
intended and perceived learning objectives, explicit or implicit
definitions of roles assumed by different stakeholders, as well
as on understanding their interaction schemes. The interviews
were conducted at 8 universities with 24 UTAs, 4 HTAs, and 8
lecturers. Our findings regarding teaching-related beliefs are
summarized in Section IV-C, the remaining findings are left out
due to space constraints.

**B. Organizational Aspects of the Courses**
To determine factors potentially influencing the UTAs’ role
at the participating institutions, we assessed organizational
conditions and the instructional material of the courses. For this,
we analyzed the organizational aspects to describe the
framework in which the UTAs act and to understand the
embedding of the role of the UTAs within the courses. In
addition to the interviews mentioned in the previous section, we
consulted also course websites and lecture material. Aspects
examined include course components (e.g., lecture, exercises,
...), UTAs’ tasks, students’ obligations, grading of homework,
and additional support offers.

In addition, we analyzed the problem sets and homework
assignments with respect to their focus because their nature can
also influence the role of the UTAs at teaching or supporting
students. For this categorization, we used two schemes. The first
scheme relies on the computer science specific taxonomy by
Fuller et al. [19]. According to this taxonomy, a problem should
be rated in the two orthogonal dimensions *Interpreting* and
*Producing*, based on the extent of which the learner has to
understand and interpret given concepts or to design and build a
new product. We use a simplified version in which both
dimensions are rated only as 0 or 1. The other scheme was based
on a standardized list of 18 operators, e.g., *describe*, *analyze*,
implement, *model*, and *proof*, that is officially used to classify
computer science problems in German high-school diploma
examinations [20]. Both schemes enable us to assess the
intended objectives of the instructor which also influence the
UTAs and their roles.

For all investigated courses, we examined all problems given
as homework exercises (between 34 and 64 problem per course)
and rated them according to both classification schemes.

All investigated courses consist of several components held
by the lecturer, HTAs and UTAs, respectively. Even though the
components in most cases have an individual course-specific
design, they can be classified into categories as follows. An
overview of the courses is presented in Table I.

**Lecture**
Each course is based on a lecture held by the course
instructor.

**HTA Recitation Sessions**
For three courses, the lecture is
complemented by global, lecture-like recitation sessions
offered held by HTAs who repeat content and discuss it
in more detail.

**UTA Recitation Sessions**
For most courses, the UTAs lead
comparatively small recitation sessions. In these
sessions, UTAs present the solutions, students work on
problems with the support of the UTA, or a mixture of
both happens. Attendance is mandatory in only one
course.

**Open Support Offer**
For three courses, UTAs offer office
hours were students can come to ask questions and to
work on the problems.

**Homework**
In each course, the students hand in homework
which is in most cases graded by UTAs. In some cases,
passing homework assignments is optional, in other
cases, it is mandatory for passing the course, and in yet
other cases, the homework grades are part of the final
grade.

**Bi-Weekly Short Exams**
Two courses offer only HTA
recitation sessions. Instead of UTA recitation sessions,
they employ weekly or bi-weekly short exams to keep
the students engaged. These exams are supervised by
UTAs and can be written or oral.

**Review Course**
At two institutions, extra review courses are
offered before the first or second offering of the final
exam. Participation in these courses is not mandatory.

At University D, there is an additional 6-week programming
course, which does not fit into any of the above categories.

The classification of the problems reflects that even though all
courses are first-year CS courses, the courses have a different
instructional design: The ratio of problems requiring the
interpretation of given concepts ranges from 21 % to 64 % and
the ratio for producing problems ranges from 58 % to 82 %. Not
surprisingly, our analysis of the operators used in
the problems shows that the most common operator over all
courses is implement. A summary of the classification of the problems for the courses is shown in Table I.

C. Teaching-Related Beliefs: Predispositions

In his review of conceptions of teaching of university academics, Kember [21] synthesized the literature under two broad orientations: teacher-oriented (or: content-oriented) and student-oriented (or: learning-oriented). Recent empirical studies with professionally trained teachers suggest that, in general, student-oriented teaching and learning environments are more effective regarding the transfer of knowledge than traditional, teacher-oriented approaches: there were positive correlations between teachers’ constructivist beliefs and student achievement gains [22], [23], [24]. It can thus be assumed that teaching-related beliefs form an important component of UTAs’ competences; those beliefs were assessed by means of interview questions related to roleperception and regarding the actual acting while teaching.

In our analysis of the interviews conducted with the UTAs, we thus were interested to see whether (untrained) UTAs expressed student-oriented or teacher-oriented beliefs. For this, we applied a qualitative content analysis [25]. The categories were formed deductively from descriptors used by Kember [21] to distinguish between the two orientations. Based upon the preliminary classifications derived from these descriptors, each interview then was manually inspected to see which orientation was dominant. In case of (near-)ties, interviews were assigned to a third category.

The transcripts of the n = 24 UTA interviews at seven different institutions were coded individually by four raters. A 3-point scale representing the three categories “student-oriented”, “mixed” and “teacher-oriented” was used, summarizing their description of how they organize and teach their courses. For example, while a teacher-oriented UTA would refer to “repetitions” and “learning best by example”, a student-oriented UTA said: “Yes, that’s what I have basically paid attention to, that it is not just that I start to talk but that I involve the students directly. Because otherwise it would degenerate to a computer lab.”

While analyzing the interviews, we learned that in some cases UTAs associated their beliefs with organizational issues. For example, some described their current approach and then used subjunctive statements expressing how they would work if they had more time. This again underlines the importance of paying attention to the organizational structure and the context of a course when training UTAs.

All ratings were then joined and summarized leading to 6 UTAs evaluated as “student-oriented” by the raters, 9 as “mixed” and 9 as “teacher-oriented”. The pairwise inter-rater reliability ranged from fair ($\kappa = 0.32$) to substantial ($\kappa = 0.73$) with a moderate overall reliability ($Fleiss’ \kappa = 0.42$). We thus concluded that UTA training sessions could not assume a homogeneity of teaching-related beliefs.

We furthermore analyzed the distribution of the teaching-related beliefs in the investigated institutions. We found that interestingly no two UTAs within the same institution had directly opposing beliefs (i.e., in all institutions we found either only “student-oriented” + “mixed” or “teacher-oriented” + “mixed” beliefs). The predominant beliefs for the courses are given in Table I. We conclude that the teaching-related beliefs depend on the context in the respective university and course. A preliminary analysis of the connections between beliefs and organizational conditions suggests that both courses with regular exams have more teacher-centered UTAs (University A and University E) which would be a reasonable connection. Both courses with student-oriented UTAs have a rather high ratio of producing exercises (University C and University F), which could indicate a fit between the course instructor’s and the UTAs’ beliefs. However, the differences in the predominant UTA beliefs seem to depend on a combination of the investigated factors or yet other factors not investigated yet (e.g., University A has a high producing ratio but teacher-centered UTAs).

D. UTA Training: Courses

Based upon the above observations and considering the spectrum of courses, we designed a UTA training course that was prototypically implemented at three participating institutions keeping in mind the organizational structure as obtained from the interviews. Two offerings were taught in parallel by one of the authors, one offering was co-taught by
another author. In line with known practices [8], the course was limited to one week with 20 sessions of 45 minutes each. The main topics covered in the course were:

**Learning Theories** In this section, an overview of fundamental learning theories was presented, i.e., behaviorism, cognitivism, and constructivism. These theories were then related to the design of assignments and recitation sessions. This section also included a discussion of constructive alignment [26].

**Structuring Recitation Sessions** The focus of this topic was on how to structure a weekly session, i.e., how to allocate time to discussing homework assignments, repeating topics taught in class, and addressing issues that came up just-in-time. This section heavily drew on the experiences of the authors with training high-school teachers.

**Critical Incidents** One of the dimensions of our competence model described in Section IV-A is *Teaching-related Tasks as a UTA*. For this dimension, we had developed an intervention and an instrument based upon the *Critical Incident Technique* [27]. In a nutshell, when using this technique domain experts are asked to concisely describe critical situations that occur in their professional practice along with a (best-practice or theoretically funded) approach to dealing with these situations. Combining these responses with carefully chosen distractors then can be used to develop an instrument. The details of how this process was run in the context of the KETTI project are beyond the scope of this paper and will be discussed elsewhere.

**Classroom Management Techniques** Pre-course surveys of new UTAs showed that many of them were concerned about classroom management, in particular about interruptions—see also the study by Luo et al. [11]. When probed for specific incidents observed in recitation sessions attended as learners, the participants consistently failed, though, to give examples. The instructors nonetheless addressed these concerns by including role plays and by discussing selected topics from a best-practice report on K-12 classroom management techniques [28]. Post-course surveys did not show classroom management to be an issue in practice. Whether this is due to the training received, a higher-than-expected resilience to such issues, or simply an artifact of the student population remains a task for future research.

**Group Work** In this section, group work techniques, e.g., collaborating in smaller groups, think-pair-share [29], or pair programming, were discussed.

Owing to the respective environments, however, the three offerings were not identical. For example, one of the courses put special emphasis on group work and role plays as the use of group work is strongly encouraged by the institution. In contrast, the courses at the other two institutions spent extra time on the construction and evaluation of assessments including a discussion of rubrics [30]; these courses also discussed peer assessments where UTAs sat in each other’s courses and gave feedback. For the validity of the observations discussed below, it should be stressed that all offerings focused on student-oriented teaching and employed constructivist activities.

**E. UTA Training: Assessment**

To assess both the perceived effectiveness of the UTA training and possible changes in attitudes and self-efficacy, we administered standardized questionnaires before (T1) and after (T2) the training. The study group consisted of $n = 56$ participants that attended the training at University A ($n = 13$), University C ($n = 32$), and University D ($n = 11$) at the beginning of the summer term 2016.

Participation in the survey was voluntary and not compensated for.

The questionnaires consisted of 28 six-point Likert-type items. For the post-instruction questionnaires, nine additional items related to the practical relevance of the UTA training and the satisfaction with the UTA training were added. Twenty items focused on expectation regarding the role to be assumed as UTA, the particular tasks to be performed as UTAs including the perceived clarity of the job description, and beliefs regarding teaching and learning. Eight items focused on self-efficacy. In addition, we surveyed demographic data such as declared major and minor, previous formal and informal teaching experiences.

1) **Subscales**

The self-efficacy items were developed based upon the previous scales used with full-time teachers. One four-item subscale focused on the general expectations and concerns regarding working as a UTA (“I am convinced that I can meet the expectations of being a UTA.”). These items were derived from the *Challenge and Threat* scales proposed by Jerusalem [31], [32, p. 81f.]. A second four-item subscale focused more explicitly on teaching in a student-centered way (“I am convinced that I can adjust to the individual problems of my tutees.”). These items were derived from a teacher self-efficacy scale proposed by Schwarzer and Schmitz [33].

To assess teaching-related beliefs, we re-used items from a scale by Staub and Stern [23]. Their scale was designed to assess beliefs regarding student- and teacher-oriented teaching in the context of elementary-school mathematics classes; hence, we restated the selected items to match our context. We used two subscales of six items each. The first subscale focused on student-oriented teaching (“My role as a UTA is to support my tutees’ active inquiry.”) while the second subscale focused on teacher-oriented teaching (“Tutees learn best from the presentation and explanations of the tutor.”)

The perceived clarity of the job description and responsibilities of being a UTA was measured using a using a newly constructed scale consisting of five items.
positive changes in self-efficacy regarding student-oriented teaching ($p = 0.022$, power: $d = 0.26^*$), student-oriented teaching beliefs ($p = 0.039$, power: $d = 0.29^*$), and clarity regarding the role and responsibilities ($p < 0.001$, power: $d = 1.24^{***}$). In contrast, teacher-oriented beliefs did not change statistically significantly ($p = 0.625$, power $d = 0.06$) and general teaching self-efficacy remained identical.

The internal consistency as given by Cohen’s $\alpha$ was acceptable with the exception of the “Student-oriented teaching beliefs” subscale in the pre-instruction questionnaire. The validity of this well-known scale [23], however, had been established in several previous studies. Instead, a manual inspection of all responses showed that several participants across all groups had single outliers, e.g., their agreement with all but one item was extremely high while they completely disagreed with the remaining items. The internal consistency of this subscale was acceptable in the post-instruction questionnaire. Thus, we conjecture that participants performed a more ad-hoc rating of isolated items in the pre-instruction questionnaire. The instruction appears to have helped them to view the questionnaire in a holistic, more reflective way. This would be consistent both with the comparable effects on teaching efficiency as observed by Dalgaard [7] and the context.
of fully-trained, i.e., not inexperienced, teachers for which the scale had been developed [23]. Hence, we consider the scales to be internally consistent at an acceptable level.

With respect to our preliminary study, the results suggest that UTA training can, despite the limited time, prepare and strengthen competences relevant for student-centered teaching. After the training, UTAs have not only extended their student-centered attitude but also have a higher expected self-efficacy regarding this. Both are central motivational factors that promote student-oriented teaching in recitation sessions.

3) Follow-Up Study:

Based on the perceived practical relevance of the training contents and the high satisfaction, it could be assumed that the UTAs were going to use and apply what they have learned. We followed up on this by administering the instruments pertaining to teaching beliefs, clarity of role and responsibilities, and the UTA training at the end of the semester (T3). As participation was voluntary, the response rate was around 50% (consistent across all institutions), leading to \( n = 34 \) responses.

The analysis comparing the post-instruction and the postteaching responses is given in Table III. It can be seen, that the teaching beliefs did not change in a statistically significant way. This indicates that the training and the practical experiences were aligned. The same holds true for the clarity of role and responsibilities.

As discussed in Section IV-D, the courses offered shared the same content when it came to topics related to our competence model. Respecting local traditions and, more importantly, to explore the decision space of the design of the UTA training, the differed, however, with respect to additional topics covered. One course (“Group A”) had been designed with competences relevant for fully-trained in-service teachers in mind. This course elaborated more on learning theories and included more detailed group work examples aligned with these theories. The other course (“Group B”) focused on more practical aspects, including assessment construction and grading as well as peer assessment. Due to the smaller size of Group B, it was also possible to cover examples from all courses the UTAs were assigned to.

The results of the breakdown of the post-teaching survey according to these groups are shown in Table IV. For Group A, both the perceived relevance of the UTA training and, correspondingly, the satisfaction with the UTA training were still positive in the post-teaching survey but had dropped compared to the post-instruction survey. Some free-text comments hinted at problems with transferring topics touched upon during the training, in particular learning theories, to the actual recitation sessions given (“instead of dealing with constructivism, I’d rather hear about how to prepare for an actual recitation session”). The results for Group B, on the other hand, did not change in a statistically significant way. Keeping in mind the small sample size and possible other influencing factors, these results suggest that UTAs are indeed “novice teachers” in the sense that they ask for more guidance and hands-on support than in-service teachers. This feedback will be used in future offerings of the UTA training courses without converting them into “grading bootcamps”.

V. CONCLUSIONS AND FUTURE WORK

A deductive analysis of UTA interviews shows that UTAs exhibit different teaching-related beliefs and that the belief appears to be related to the organizational context: In some courses, the UTAs have a more teacher-centered and in other a more student-centered attitude. A prototypical implementation of a UTA training course showed significant positive changes in the subscales relevant for student-centered teaching. Preliminary results also seem to confirm that UTAs are different from in-service teachers and that thus a specialized competence model and corresponding training is warranted.

The categories of our preliminary competence model for UTAs have proven to be relevant for exposing differences in the competences and perceptions of UTAs; the model will be developed further to refine these categories. For this, a detailed qualitative content analysis of the interviews with the UTAs, HTAs, and lecturers is being conducted to reveal and collate the perspectives of the different stakeholders.

We have assessed the UTAs’ attitudes and self-efficacy again after one semester of working and have obtained a confirmation of the retention of the concepts. Currently, we are investigating the influence of practical experiences on the development of competences. For this, we are in the process of observing UTAs acting in recitation sessions to compare the perceived and self-reported role with the teaching observed. These observations are also likely to be useful for a further refinement of the competence model.

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