First-Year Computer Science Students Perception of Lectures in Relation to Type of High-School Education

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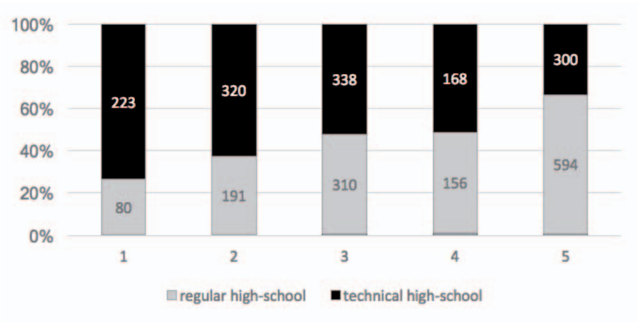
Abstract— **During the first year of computer science studies, students frequently experience difficulties, which can have multiple reasons. We have observed a tendency that students with computer science education at high-school seemed to be more confident and successful in their studies than students with a regular high-school education. As we experienced differences in particular during lectures, we were interested in both groups' perception during lectures that nudges students' way towards success or failure in order to identify possible pitfalls for students without computer science pre-education. To this end, we set up a mixed-methods research consisting of a pre- and post-term questionnaire as well as interviews and group discussions. We asked students about their experiences with teaching and during the first-year at our university. First results indicate that there are no significant differences in both student groups regarding the perception of teaching and teaching methods. However, students with no computer science high-school education are more likely to struggle with introductory coding classes, in particular at the beginning of their first term.**

Keywords— Quality in teaching, first-year experiences, first-year computer-science studies)

I. Introduction

The computer science (CS) program at our university faces currently two major issues: a gender gap and a high dropout rate. Therefore, we set up a project aimed at improving the first year in computer science program with regard to organization, quality of teaching and students' experience in order to tackle these issues. As a first step towards evidence based measures, we were evaluating the first-year of computer science studies from different perspectives. For this part of the study, we set up a mixed-method research design to investigate the underlying reasons for the gender gap and the high dropout rate. One of our key questions in this regard is subject of this paper: Do teaching faculty members in their teaching practice reach out to all students equally or is there a perception gap for diverse student groups? Moreover, our assumption is, if teaching is not perceived by all students equally or respectively, if teaching does not address all students, it could be a reason for an attainment gap as well as a reason higher dropout rates. It is important to know that secondary education in our country is very diverse and includes high-schools, which offer explicit computer science education and regular high-schools where no computer science education is offered. Consequently, some beginners have more domain-specific knowledge than others. The administrative student data of the beginner cohort 2015-16 indicates that students' grade performance differs according to their diverging high-school education (Figure 1). Throughout several beginners' classes students without domain-specific pre-education obtain less good grades than students who attended a computer science high-school. Data from previous years indicate similar trends.

FIGURE 1: DISTRIBUTION OF EXAM RESULTS FROM GRADE 1 (VERY GOOD) TO 5 (UNSATISFACTORY/FAILED) IN 2015/16 FROM STUDENTS WITH REGULAR HIGH-SCHOOL PRE-EDUCATION AND COMPUTER SCIENCE HIGH-SCHOOL EDUCATION



The influence of beginners' divergent pre-education on their performance as university student is multifaceted. Adelman [1] showed that the academic quality and the intensity of a student's high school curriculum is a key factor for college graduation. Moreover, pre-knowledge in programming impacts students' development during the first-year in CS studies. Alvarado et al. [2] showed, that prior experience, confidence and comfort, respectively, increase students' first year performance in CS studies. Also, students' high-school math performance, and gender impact their success [3]. Barker et al. (Exploring Factors that Influence Computer Science: Introductory Course Students to Persist in the Major) pointed out that male gender is positively correlated with the intention to major in CS. Furthermore, female students also indicated reasons for low satisfaction in faculty-student interaction and student-student interaction. Moreover, students without pre-experience in programming reported discomfort during lectures [4]. At the same time, students with a high-school programming course are more likely to succeed in a college CS course [5] and perform better than those without previous programming experiences [6], [7]. Altogether, there are manifold factors that influence students' attainment gap [8], pre-knowledge and experience is a crucial one. Despite numerous studies indicating a correlation between school education and success in a university program, little is known about the perception of teaching by students, and whether it is impacted by previous learning experiences. The question is whether the attainment gap, as indicated by the difference in performance (Figure 1), is not only based on the starting advantage of pre-knowledge but that it is further deepened by a diverging in perception of teaching. Or to put it another way: If teaching were to reach only students with domain-specific pre-education, students with an experience gap might further loose and be more likely to drop out. In this paper, we therefore examine beginners' perception of teaching in the first-year CS studies and how this perception might differ if they had CS at high school or not. Hence, our goal is to find out, if a designated CS education on secondary school level impacts students' perception of first-year CS lectures. Considering this, we have formulated the research question: *Is there a difference between these groups in the perception of first-year lectures?* The paper is structured as follows: First we describe the methods, participants, and process of analysis we used to investigate the research questions. In section three we present quantitative and qualitative results and in the fourth section we discuss our findings and draw conclusions for further work.

II. METHOD

We gathered data from throughout the academic year 2016/17. By applying a mixed-method approach, we are combining qualitative and quantitative instruments. The qualitative part of the study included interviews and a group discussion with students. The data collected provided insights on both the students' and lecturers' perspective of the first year. Furthermore, we captured students' experiences and the potential change over time through a pre-/post-questionnaire, which was distributed to all beginners at the beginning of the first term and repeated it in the second term. In order to identify possible differences between both student groups corresponding to the research question, we considered throughout all instruments and participant selection a balance to improve the comparability of the data.

A. Participants

The cohort of students in our study were all beginners who started to study CS in October 2016, in total 517 students. The students were enrolled in different bachelor programs: Informatics and Visual Computing, Medical Informatics, Software & Information Engineering, Computer Engineering, or Business Informatics. Three courses are compulsory in all bachelor studies, except for Computer Engineering, where the lecture computer engineering is replaced by a more specific one.

1) Survey

The survey targeted also all 517 beginners who enrolled CS by October 2016. We distributed paper/pencil questionnaires in the lecture "Algebra and Discrete Mathematics" in October 2016 in the second week after the term as started. This is a compulsory course for all CS students. 235 students returned this paper/pencil pre-questionnaire (response rate of 45,5%). The second survey was carried out in March 2017 online with email invitations sent to all beginners of the winter term. Even though we have sent multiple reminders and even offered vouchers as incentives, only 91 students completed the second questionnaire (response rate of 17.6%).

2) Interviews and group discussion with students

During the first term, we invited all first-year students to attend a group-discussion in our office. Three students followed our invitation, all were male, two of them had no and one had a domain-specific pre-education. Further eight students volunteered for an interview; all of them had no pre-education in computer science. In total six females and eight male beginners participated in the qualitative study, which is close to gender parity. Table 1 summarizes characteristics of the participants in qualitative study. The first column comprises the anonymized label of the student, the second their gender and the third shows whether the student had a focus on computer science in their high school education or not. To make the distinction between students with computer science high-school education and without computer science high-school education we assigned the letter A to students without computer science high-school education and the letter T to students with computer science high-school education. We are aware of a selection bias as it is likely that the students who followed our invitation are generally more interested to share their experiences. As mentioned in the section about limitations of this study below, we were not able to reach out for an interview to student groups as drop-out possible candidates. They either already have left our college or didn't respond to invitations. Nevertheless, we were able to recruit a selection of students representing a mix of gender and high-school background. Interview data was taken into account to deepen insights we obtained from the questionnaire.

TABLE I. BACKGROUND OF INTERVIEWES STUDENTS

ID	Gender	High school education
A1	male	no computer science
T2	male	computer science
A3	male	no computer science
A4	female	no computer science
A5	female	no computer science
T6	male	computer science
A7	female	no computer science
A8	female	no computer science
A9	female	no computer science
A10	male	no computer science
T 11	female	computer science
T 12	male	computer science
T 13	male	computer science
T 14	male	computer science

B. Instruments

Data collection was carried out by two research assistants. As a quality check, the different instruments were discussed by a board of external and internal experts. All participants were informed of the study aim and how results contribute to our project.

1) Survey

To capture the changes in experiences, we conducted one survey at the beginning of the first term and a follow up survey at the beginning of the second term. The questionnaire for both surveys was developed based on a literature review on students' dropout. We asked in both surveys items regarding classroom climate based on [9], [10] the perception of courses, lecturers, the overall impression in [8], [11], [12], and the infrastructure. Further items were used to capture gender stereotypes and students' demographics. Both questionnaires also included an open question to submit suggestions what the university could improve. As dependent variables, we asked about satisfaction with the program, thoughts about dropping out, confidence to graduate as well as to continue in a post-graduate study program. The first questionnaire further included questions regarding study choices and an open question to describe the first day at university. In the second round, students were asked to describe a course that was exceptional, as well as to self-assess how well they did in the course program construction.

2) Interviews and group discussion

In the interviews, we asked the beginners to openly talk about positive and negative experiences they made and what suggestions they have for improving the first year of CS studies. We referred to some of the questionnaires' questions and encouraged students with low grade performance to tell us possible reasons for their difficulties. The interviews with students and the students' group discussion were carried out midterm by two research assistants, whereas one was the interviewer and the second one was responsible for audio recording and took notes. Data analysis was carried out by the authors of this paper, and is described in the following section.

C. Data Analysis

1) Quantitative

Once the data was entered and downloaded, respectively, it was cleared of inconsistencies and a descriptive analysis was conducted. To check and to build a teaching scale, a principal component analysis regarding the perception of lecturers and teaching style was conducted for Survey 2 (Survey 1 comprised less items on the perception of teaching as students were in class for only one week at that time). Nine items were included which produced a factor on "qualitative teaching", on "respectful teaching" and on "interactive teaching", with a KMO measure for the all factors of 0.70 and for all individual items above 0.52. The factor "respectful teaching" was also tested in Survey 1 and produced a KMO measure of 0.65 and for all individual items above 0.58. Moreover, a reliability test was conducted for the factor "respectful teaching" (Survey 1, Cronbach's $\alpha = 0.73$; Survey 2, Cronbach's $\alpha = 0.67$) as well as "qualitative teaching" (Survey 2, Cronbach's $\alpha = 0.72$) and "interactive teaching" (Survey 2, Cronbach's $\alpha = 0.59$). Additionally, to the saved factors, a variable for each of them was computed, comprising the mean of the following items:

Respectful teaching (Survey 1 and Survey 2): "Teachers treat students with respect.", "It is okay to ask the teaching staff a question." and "I feel I am taken seriously as a student."

Interesting teaching (Survey 2): "In general, classes are taught well.", "I like the teaching methods of this programme.", "I consider this programme as interesting." and "Classes are fun."

Interactive teaching (Survey 2): "There was enough space during lectures to interact with the teaching staff." and "Lecturers tried to include students interactively during class."

Since it was aimed to find out if students with computer science pre-education perceive the teaching style differently, we compare the means of these scores between the group of students with and those without domain-specific school education, conducting an t-test for the three perceived teaching styles.

D. Qualitative

The analysis of the qualitative data deriving from interviews and group discussion was carried out in accordance with the qualitative content analysis as pointed out by Mayring [13]: First we applied a deductive approach based on pre-defined categories, followed by a summarizing interpretation of the results. Therefore, we first transcribed the audio recordings of interviews and group discussions exactly and added the notes from the lecture observations. Following to Mayring's deductive approach, we first assigned text units to our predefined categories. These categories derived from our research questions (the ones from this paper and others) and are captured with the labels *teaching, learning, methods*. As unit of analysis we used 1-3 sentences.

Example. Considering the following source data from a student interview:

> *The teacher tries to combine the lecture slides with practical examples. But in the lecture, itself inventive methods are rare.*

Each sentence of this paragraph was sorted into different categories. The first sentence was sorted to **Teaching** and the second to **Methods**. From a critical perspective, both phrases were possible candidates for the category **Methods**, but we followed a consistent rule, that if teaching in action is mentioned, it will be sorted to **Teaching** and if methods in a rather structural way are mentioned, it will be sorted to **Methods**. We were also aware of a possible bias when just one coder is involved in this process and multiple coders would increase the intercoder-reliability but we were limited in personal and time for carrying out the qualitative analysis. But we circulated the results of the results within our research group and discussed rearrangements of data in categories. After we went through the material and coded the transcript into categories, we used in a second step Mayring's technique of summarizing content analysis for interpretation. For this technique in analyzing, Mayring suggests in [13] for the summarizing content analysis the following steps from Z1 to Z4 (the letter Z comes from the German word *Zusammenfassung*, which means *Summarizing*):

- Z1: Paraphrasing and remove passages without content
- Z2: Generalization to the level of abstraction
- Z3: First reduction and deletion of paraphrases with same meaning within the unit of analysis
- Z4: Second reduction: Summarizing of phrases with similar meaning

This process of analysis is commonly used for building categories inductively. We used the Z-reduction process to summarize and generalize text phrases, which were sorted into the categories in the previous step. The table below gives an example of the process of Z-reduction as it was applied this analysis. Beginning with the coded quote of our source material, we generalized, paraphrased and summarized the content of the data.

TABLE II. SNIPPET OF Z-REDUCTION

Source	Z1	Z2	Z3	Z4
"It seems, that the teacher sometimes just does not answer our questions. Some of the students can't follow anymore. "	The teacher does not answer students' questions and students cannot follow the lecture any more.	Students' questions are not answered Students can't follow any more	As the teacher does not always answer students' questions clearly, students have difficulties in understanding content	As the teacher does not always answer students' questions clearly or questions are unclear, students have difficulties in understanding content.
"Most of the time, the teacher asks questions, where no distinct answer is probably possible and we the teacher then say that he does not reply now in detail. "	The teacher asks questions which are hard to answer and does not explain further details.	The teacher's questions are unclear Students say that the teacher's questions can't be answered in detail.	Teacher's questions unclear.	
"Sometimes, I ask a question. "	A student sometimes asks a question.	A question is asked sometimes	A student asks only sometimes a question.	

When the data was at level Z4 we subsequently continued with interpreting the remaining information as suggested by Flick and Mayring [14], [15] with the aim to find an objective meaning of text data in comparing different views on it. This process included the comparison of Z4 results with each other and with the original text. Furthermore, we discussed results and developed explanations of Z4 outcomes and further developed answers to the research question we asked respectively compared it with quantitative results of the survey.

III. RESULTS

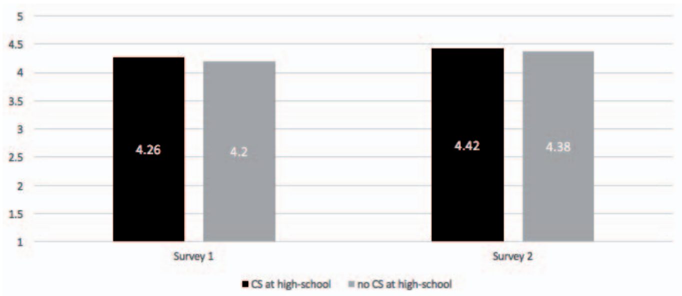
In the following, we summarize our preliminary results in regard to what are the lecturers' and students' expectations and experiences during the first year of CS studies.

A. *Survey*

1) *Respectful Teaching*

At the beginning of their study students with and without domain-specific CS school education did not show statistically significant difference in their perception of "respectful teaching". As it is depicted in Figure 2, at a scale from 1 (strongly disagree) and 5 (strongly agree) "respectful teaching" scored 4.26 from students with and 4.20 from students without domain-specific school education (Figure 2). This difference is statistically not significant. In survey 2, however, the scores for "respectful teaching" are higher than in survey 1, with an average of 4.42 from students with and 4.38 from students without school-education in computer science.

FIGURE 2: RESPECTFUL TEACHING



2) *Interesting Teaching*

The scores for "interesting teaching" and "interactive teaching" also do not significantly differ between those with and those without CS school education. Students with CS school education agree (on the scale from 1 to 5) in average with 3.65 those without computer science school education agree with an average of 3.61 that their classes are in general well taught and interesting.

3) *Interactive Teaching*

These results score a bit lower, with 3.36 for students with and 3.26 for students without CS school education. However, there is also no statistically significant difference between students with and those without domain-specific pre-education. To sum it up: even though there is a difference in the perception of teaching due to pre-university learning experiences, this difference is not statistically significant. In general, the teaching scores higher when it comes to "respectful teaching" and more mediocre when it comes to "interactive" or "interesting teaching".

B. *Interviews and Group Discussion*

Results of the qualitative study provide further details about students' perception of teaching, where only a marginal difference was identified between students with and without domain-specific/computer science pre-education in the perception of the first-year classes teaching. As mentioned above, we selected, for the purpose of this paper, the categories teaching, learning, methods to discuss the perception of beginners' classes (*A* are students marked without computer science high-school education and the *T* to students with computer science high-school education). The next subsections present students' phrases from the transcribed source which turned out during the process to be important in evaluating and interpreting the reduced representation of the data. The overall interpretation of the results will be presented in the discussions section afterwards.

1) Category Teaching

According to our study participants lectures with a high number of participants are difficult to follow. Some students described those classes, in which an additional member of the teaching staff was present, as more interactive and interesting. Furthermore, the teaching content can be challenging, especially for students without CS high-school education. This can be helped, if practical examples are used, as is pointed out by the following student:

A9: *When professors gave practical examples, I was able to understand the content better.*

At the same time, students with CS high-school education appreciate to be challenged in classes:

T14: *In the lecture, the professor always tried to teach the material comprehensively. In combination with the quite extensive exercises and practice test, I was always challenged, which in my opinion is very helpful in the first semester.*

The discrepancy does not stop in the content of teaching but also in the perception of the teaching climate. While students with CS high-school education emphasize the passion, they perceive from the teaching staff, those without CS high-school education rather express feelings of pressure and discomfort with the teaching style, as the following two quotes highlight.

T13: *It is evident that the lecturers are passionate about their subject. The lecturers were presented with enthusiasm and it was easy to understand and enthralling. The best lecturers were able to convey their knowledge to everyone.*

In contrast, a student without background in computer science perceived the climate differently:

A7: *I did not like the atmosphere because I felt intimidated by the graduates from computer science high-schools (especially the men), when I had questions about mathematics or programming, and during the program-construction exercises, I also felt a lot of pressure from the lecturer. It all led to the fact that at the end of October I was just uncomfortable at the university, and I was very stressed and tired.*

Altogether, it appears as if the perception of teaching differs according to the pre-university education. However, teaching faculty members can react to this in using practical examples that allow students without domain specific pre-education to catch up with their peers.

2) Category Learning

Some students stated that without continuous learning it would not be possible to keep track with the lectures. It is necessary to have a high amount of self-motivation. Diligence and perseverance are required to manage the huge amount of learning material. Learning is perceived to be easier, if teaching material is consistently presented in books, lecture notes and presentation slides. This means, that students prefer a consistent presentation of teaching content throughout the course and the different learning material. One student, for instance, mentions that it is difficult to learn from the presentation slides used by the lecturer:

T2: *From the slides in the programming lecture I cannot learn anything.*

Sometimes students identify that lectures overlap in content but they miss an explicit "golden-thread".

Another student mentioned that practical examples are important for understanding content in theory.

A5: *It is good when you learn a theory, but I learn them much better if I myself do something about it in practice.*

This issue is remarked upon by both students with and without CS high-school education.

Students without CS high-school education experienced the need for more effort in learning compared to students with CS pre-education. In line with this, students without CS high-school education find it harder than their peers with CS education to gain the demanded level of knowledge during the first term

A7: *I came from a school with no focus on computer science education, so I had a lot less knowledge than the computer science high-school graduates and it was just too hard to keep up.*

A10: *I do not think the design of the beginners' lectures is so good. The first half of the programming lecture can be mastered with the school knowledge, I unfortunately missed it and lost the connection.*

In sum, both groups prefer lectures and learning material to be consistent, indicating that this might not always be the case. Moreover, students without CS pre-education struggle with the high learning demands ask for material they can relate to more easily, in order to catch up with their peers who have domain-specific pre-education.

3) Category Methods

Occasionally, lecturers try to integrate small group-work into lectures but students rarely see a benefit in this method as it is not well-organized. Students state that even in big lectures the teaching staff aims to include interactive elements, such as asking questions like 'Is this clear?'. Yet, this type of intervention appears to be rather meaningless as students perceive these as rhetorical statements that do not require any response nor provide opportunities for questions. Here, students with and without CS high-school education coincide.

Nevertheless, there are indicators that the perception of interactions during classes and the lecturers' motivation differs between students with and those without CS high-school education, as the following quotes show.

A1: *Questions to lecturers are generally well-answered.*

T2: *Sometimes it is like the teacher does just not answer questions. A lot of students can't follow them anymore.*

Hence, it turned out, that teaching methods in general are perceived positively if they have an emphasis on teacher interaction with students.

IV. Discussion

The administrative data as well as the literature suggest that students' school education and whether they obtained domain-specific knowledge prior to enrolling at university impacts students' attainment. In particular, students with domain-specific pre-education are more likely to obtain better grades in the first year than students without such pre-education. Moreover, students with pre-experiences in programming and pre-knowledge in CS are more likely to persist. One reason for this attainment gap could be that students perceive teaching different, depending on their diverging educational background. Results of this paper suggest that there is only a marginal difference students perceive and experience the first-year lectures of CS. By tendency, students without domain-specific perceive the teaching a bit more skeptical than their peers with relevant pre-education, however these differences are not statistically significant. Qualitative data furthermore suggest that students of both groups identify teaching and teaching methods as beneficial or not and it can be assumed that this perception depends on a student's personality rather than the student's pre-education. When it comes to the perception of learning experiences, qualitative data showed some differences between these groups. For students without computer science pre-education more time and effort was required to keep up with the lectures, in particular the introduction into programming. Even if our results showed no differences in students' perception of first year teaching, we were able to show, that students' type of prior education has no impact in the perception of teaching methods and teaching style. Instead, the CS high-school education of students is obviously an important factor for efforts in learning. This seems to be evident, as students with computer science pre-education already have learnt content what they learn again in their first year of computer science. Based on these results it seems to be even more important to further investigate the non-computer science pre-educated students' difficulties in learning during the first term. In order to identify possible pit-falls we will further investigate both student groups with a focus on their learning experience in order to be able to introduce focused measures.

V. Limitations

The results must be considered in light of several limitations regarding the data and generalizability of the findings. First and foremost, the questionnaires were filled out at the beginning of the term by 254 students and at the end of the term by 92 students and we were able to match only 42 students out of them. Furthermore, we were not able to include known drop-out candidates in our study as no one of the students who left at the time of the study the university responded to our requests for an interview. In general, during the collection of qualitative data, we had difficulties to acquire students for interviews or group discussions and it became even more difficult during the term. Even if we were still able to draw statistically valid conclusions and interesting qualitative insights, a higher amount of responses would be preferable and required for further work.

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