Computer Science in the Eyes of Its Teachers in French-Speaking Switzerland

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Abstract. This paper discusses the situation of high-school-level Computer Science education (CSE) in the French-speaking part of Switzerland through the eyes of Computer Science teachers. After presenting the peculiarities of the educational system in a federal state like Switzerland and its impact on CSE, we try to answer several questions about CS teachers, their profile, and their representations of the field. Recognizing that the primary field of study of most current CS teachers was not CS, we question their representations of CS in search of potential differences between specialists and non-specialists. On this basis, we analyze the distance between CS as it is taught in French-speaking Swiss high schools and CS as its teachers think it should ideally be taught. Finally, we present the important need for continuing education of CS teachers and the fact that, according to them, it should include both technical and didactic aspects.

Keywords: Computer science · Computer science education · Computer science teachers · Swiss high schools · Representations of the field · Continuing education

1 Introduction

This paper is concerned with several issues linked to teaching Computer Science education (CSE) in French-speaking Swiss high schools, presented according to the following structure. Section 2 presents the characteristics of the Swiss educational system, its impacts on the organization of CSE in high schools and the situation of CS teachers. Section 3 outlines our research questions and our methodology to collect data. We then present and discuss our results in Sect. 4 and sum them up in the conclusion as Sect. 5.

2 Historical Elements and Context

Switzerland is a federal state composed of 26 cantons and half-cantons. Since their origins, Swiss people have considered very important to give cantons a lot of independence from the federal state. It is apparent in a lot of dimensions: political, economic, educational, to name a few. This organization has a lot of

A. Brodnik and F. Tort (Eds.): ISSEP 2016, LNCS 9973, pp. 179–190, 2016.
DOI: 10.1007/978-3-319-46747-4_15

positive aspects, letting political decisions be taken by people who are close to the field, but also less positive ones, leading to a greater complexity.

This also holds for education. Education is mostly managed at a cantonal level, which means that Switzerland has nearly 26 different educational systems with 26 education ministers. Some processes and instances do exist to try and coordinate decisions and systems between cantons, but nevertheless education politics remains complex to understand.

The Case of High Schools. Even if high schools depend from the cantons, students obtain a so-called "federal maturity" when they graduate from them—"federal" meaning that it is valid in the whole country.

The country-wide recognition of high-school diplomas is regulated by a federal document (hereafter referred to as "RRM"[1]). Cantons must conform to the rules listed in RRM in order for their diplomas to be validated by the state [4]. RRM establishes globally the fields that must be taught in high schools along with the rules for certification. In more details, it distinguishes four main teaching domains (languages, mathematics and sciences, humanities, and arts) and three lists of disciplines: (*a*) fundamental fields, which must be taught to all students; (*b*) so-called "specific options," which can be viewed as the high-school version of college majors; and (*c*) complementary options. Students have to choose a single specific option and a single complementary option; therefore, each of them only concerns a (possibly small) subset of students. RRM doesn't dictate the number of teaching periods assigned to each field, but only gives an indicative proportion of each of the four domains. It also doesn't describe the contents of the fields. Cantons have the liberty to propose canton-specific disciplines in addition to the RRM-mandated ones.

In this context, RRM is the most important document that exists. The version of RRM valid today was written in 1994, with some adjustments made in 2007.

With RRM having established the fields of teaching and learning, there is a second document (hereafter referred to as "PECMAT"[2]) established by the Swiss Conference of Cantonal Ministers of Education ("CDIP"[3]). It describes a short "curriculum framework" for each discipline mentioned in RRM. It is not legally binding, but makes recommendations to the cantons [2]. PECMAT dates to 1995 and a complementary part was written in 2008 to reflect the changes introduced in RRM in 2007.

Based on PECMAT, the cantons each establish their own operational curricula, which serve as reference for teachers. The process ends here with 26 cantonal curricula for each field (for instance, [5,7]).

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[1] *Règlement de reconnaissance des maturités* or *Anerkennung von gymnasialen Maturitätsausweisen.*

[2] *Plan d'études cadre pour les écoles de maturité* or *Rahmenlehrplan für die Maturitätsschulen.*

[3] *Conférence suisse des directeurs cantonaux de l'instruction publique* or *Schweizerische Konferenz der kantonalen Erziehungsdirektoren.*

Computer Science in High Schools. In the 1994 version of RRM, CS didn't exist as a field, but was only mentioned as a collection of transdisciplinary topics. In the period from 1994 to 2007, considering the lack of CS or related field in the federal rules, some cantons decided to make use of their freedom to introduce CS as a cantonal field.

There are no studies about the motivations of the cantons to introduce CS as a cantonal field at that time, so uncertainty remains as to how this process precisely occurred. Certain is that it was made independently of any federal recommendations, so each canton decided on its own on the contents to be taught. Without aiming at providing a detailed look at those cantonal curricula (which would be outside our current scope), a quick look at them reveals that the contents of this field called "Computer Science" (*informatique* in French) is closer to teaching and learning the use of traditional software tools (word processing, spreadsheets, etc.) than to the academic discipline as we identify it today. It seems that the preoccupation of education ministers at that time was to make sure that students were able to produce proper presentations, written texts and graphs for their school work. If it were done today, we would certainly question the relevance of the name of "Computer Science".

In the 2007 addendum to RRM, CS was introduced at a federal level as a new discipline in the list of complementary options. For the first time, the opportunity was given to students to study CS as a scientific field. An addendum was written to PECMAT to propose a description of the contents of this new course and, in a typical process for Switzerland, each canton wrote its own operational curriculum. A quick look at the PECMAT addendum or at the cantonal curricula derived from it shows that the mentioned themes are closer to CS as a scientific field and not so much related to the use of software tools.

The addition of CS as a complementary option was considered a major improvement by people concerned by the state of CSE in the country. But owing to the nature of complementary options, only a few students actually got to study CS that way and the concrete impact of this new course was thus limited.

In reaction to the introduction of CS as a complementary option in RRM in 2007, a few cantons decided to suppress the CS cantonal field they had introduced before, but the majority of them kept both. Today, the resulting situation can be characterized this way: very diverse depending on the canton, with mostly two kinds of CS courses side by side in the curricula: one cantonal with an emphasis on the use of software tools (referred to later as "cantonal CS"), and one federal with a scientific orientation (referred to later as "complementary-option CS")—both of them named "Computer Science".

In 2013, CDIP gave mandate to one of its subgroups to write a report about the introduction of CS in high schools as a fundamental field for all students. In this mandate, CDIP clearly states that the presence of CS in high schools must be strengthened in regards to its importance in society nowadays [3]. As we write this article, work towards the final report is reportedly in progress. If that report recommends the introduction of CS as a fundamental field, political decisions will need to be made in order to adapt the structure of the domains and curricula in high schools, as well as the official documents (RRM and PEC-MAT). Understandably, said mandate generated high expectations among CSE professionals, who see a true opportunity for the introduction of CS for all students in Swiss high schools in the near future. The impacts of such a decision could be very important, in particular for CS teachers.

Situation of Teachers. In the 80s, computers were introduced in Swiss schools before any CS curriculum existed. Teachers who graduated in CS didn't exist either. CS curricula were not so widespread in universities and as there was no CS in schools, there was no reason for a CS specialist to work as a teacher. Often, mathematics teachers or physics teachers (sometimes teachers of other fields) got in charge of managing the school computers because they were the only ones who had ever seen computers during their college studies. Quite naturally, when some cantons later introduced CS curricula in their schools, those same teachers started teaching it. Even if it is a mandatory rule that high-school teachers must hold a Master's-level degree in their field of teaching [4], at the time, a margin of tolerance existed, supposedly due to the fact that CS was canton specific.

Things gradually changed and starting around 2000, more students holding a Master's degree in CS have been seen entering teacher-education programs and becoming CS teachers in high schools.

When CS debuted as a complementary option in RRM in 2007, there was an important need for CS teachers with an academic background in CS. An ad hoc continuing-education program in CS was proposed to non-specialist teachers who were already in charge of the cantonal CS course. Between 40 and 50 teachers graduated from that program.

3 Research Questions and Methodology

In short, the situation of CS in Swiss high schools is a bit confusing: the federal course as a complementary option coexist with the cantonal course, both being named "Computer Science", but with different contents. Some curricula focus on the use of software tools while others are closer to academic CS. CS teachers have different profiles, some of them being CS graduates, some others being primarily specialists of other fields. In addition, each canton has its own organization and curricula.

As we might be on the cusp of major change with the potential introduction of CS for all at a federal level, there is a need to clear up the confusion and get a better understanding of the current situation.

We decided to focus our efforts on the following research questions:

1. *What is the proportion of CS teachers who primarily graduated in CS?*
2. *Do teachers with different backgrounds view CS fundamentally differently?*
3. *What are the differences between ideal CS teaching, complementary-option CS, and cantonal CS in the eyes of the teachers?*
4. *What topics do CS teachers need in continuing education?*

Our method of investigation is based on a survey addressed to CS teachers. As our institution is involved in the education of teachers for the French-speaking part of Switzerland, we focused on that part of the country. The survey was sent to teachers through one of the most important professional associations of CS teachers in Switzerland, the Swiss Society for Computer Science in Education (SSIE[4]).

The survey was composed of four parts: 1. teachers' profile (academic and pedagogical studies, current teaching); 2. needs for training; 3. representations of CS and CSE; 4. opinion on a potential CS course for all students.

In order to better design our survey, we ran a preliminary version of it during three personal interviews with three CS teachers who had different profiles and backgrounds. We then proceeded to some adjustments to better fit our goals.

4 Results and Discussion

The total number of respondents was $N = 37$. The population size (i.e., the exact number of CS teachers in French-speaking Swiss high schools) is not known to us as we could not readily obtain such information from the cantons, but we estimate it to be between 150 and 200.

Like for most surveys based on voluntary participation, the sample formed by the respondents may be biased in several ways. We expect teachers with an interest in the development of CS teaching to be more likely to participate. In particular, we noted a large representation of a special subpopulation: teachers who participated in the CS continuing-education program mentioned at the end of Sect. 2, offered when complementary-option CS was introduced. We also expect teachers in need of continuing education to be more likely to want to give their input. Finally, we had no way of ensuring that every member of the population would effectively be notified of the survey.

Question 1. Figure 1 shows the initial fields of study of the respondents (as multiple answers were possible, the numbers add up to more than 37). Although most of them (31, about 84 %) primarily studied at least one STEM[5] field, only a minority (15, about 41 %) studied CS.

Older teachers are less likely to have primarily studied CS—as mentioned before, an obvious reason is that CS curricula were not as widespread as they have gradually become now. Since the late 90 s especially, a growing number of CS curricula have been proposed, a lot of them by the newly appointed universities of applied sciences[6]. We actually found out that the proportion of CS graduates was substantially larger for teachers who graduated after 2000: 8 out of 11 (73 %) vs. 7 out of 25 (28 %) for those who graduated before 2000.

[4] *Société suisse pour l'informatique dans l'enseignement* or *Schweizerischer Verein für Informatik in der Ausbildung*.

[5] Science, technology, engineering, and mathematics.

[6] *Hautes écoles spécialisées* or *Fachhochschulen*.

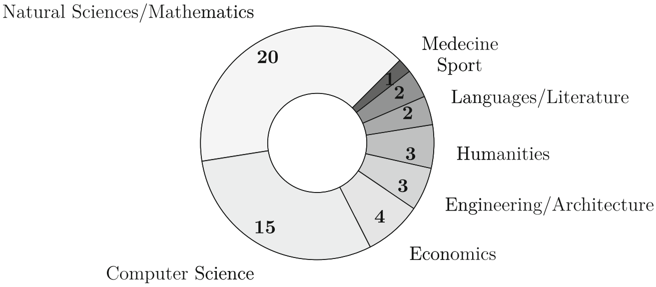

Fig. 1. The fields of initial studies of the respondents.

Question 2. Do teachers with different backgrounds view CS fundamentally differently? We asked respondents to indicate, for each of these items, whether they completely disagree, somewhat disagree, somewhat agree, or completely agree with it.

"Absolutely spoken, outside schools, computer science...

1. is mainly applied mathematics" (hereafter referred to as the AppliedMath subquestion)
2. doesn't really have stable components and changes all the time" (NotStable)
3. changes rapidly, but rests on stable notions that do not change a lot" (StableNotions)
4. has theoretical foundations" (HasTheory)
5. focuses mostly on abilities to use software tools" (Tools)
6. mainly represents know-how rather than concepts and notions" (KnowHow)
7. is the major science of the 21st century" (MajorScience)

Looking qualitatively at the respondents' education profiles, we categorized them into three groups: (G_1) those whose primary education was CS ($N_{G_1} = 15$); (G_2) those whose primary education was not CS, but who had complementary or continuing CS-related education ($N_{G_2} = 17$); (G_3) those who had no CS-related education other than being self-taught ($N_{G_3} = 5$; $N_{G_1} + N_{G_2} + N_{G_3} = N = 37$). Comparative results on each subquestion, for each of the three groups and for all respondents together, are shown in Fig. 2.

These results show the following. 1. CS is considered by more than 80 % to be more than just applied mathematics. 2. Less than 5 % think that CS doesn't have stable components. 3. All but one respondent somewhat or completely agreed that CS rests on stable notions. 4. Less than 5 % disagreed that CS has theoretical foundations. 5. About 20 % are of the opinion that CS is mainly about how to use software tools. 6. Most (more than 80 %) disagree that CS mainly represents know-how. 7. More than 75 % somewhat or completely agree that CS is the major science of this century.

Although small group differences can be observed, Kruskal–Wallis H tests [6] conducted for each subquestion revealed that only subquestions HasTheory ($H(2) = 8.37$, $p = 0.015$) and KnowHow ($H(2) = 6.71$, $p = 0.035$) exhibited

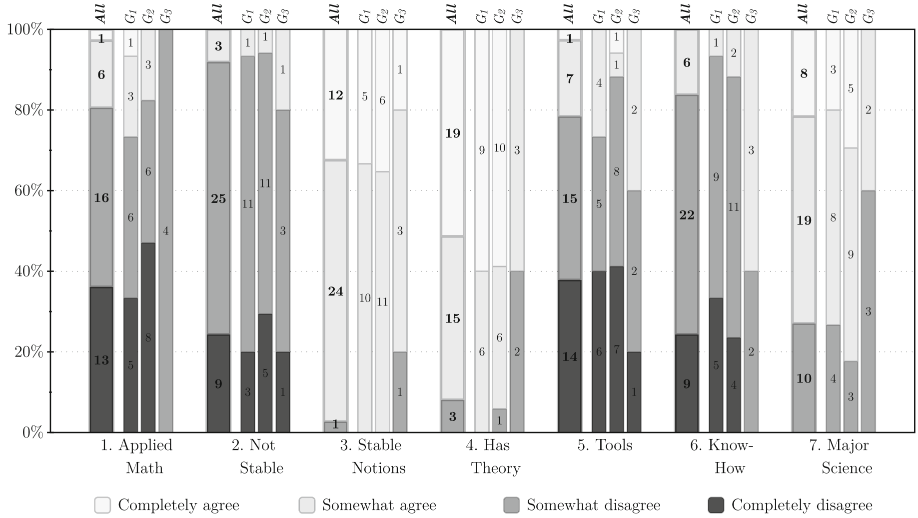

Fig. 2. The respondents' declared agreement on the nature of CS on 7 axes. Data is shown for the whole sample and for the three discussed subgroups.

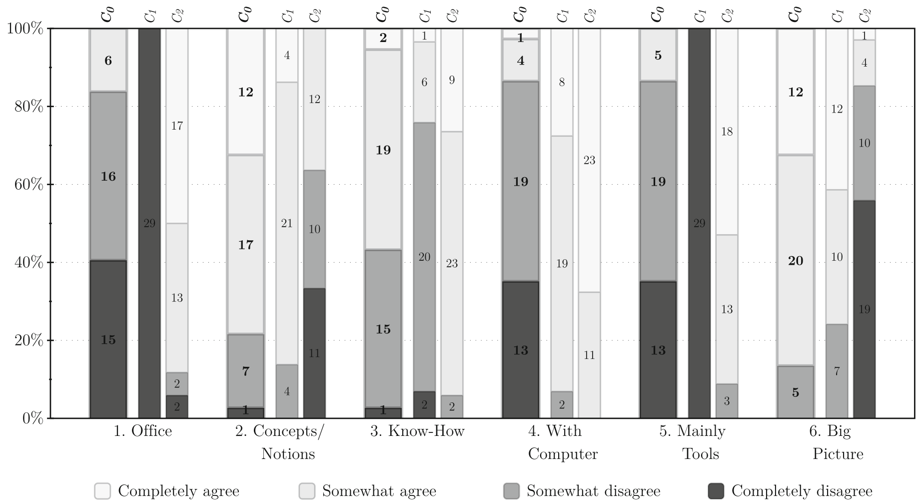

Fig. 3. The respondents' view on what CS teaching should be ideally (C_0) vs. what it is for two course types currently given in high schools (C_1 and C_2).

statistically significant differences between our three groups. In the former case, the self-taught group was significantly less likely to agree that CS has its own theoretical side; in the latter, they were significantly more likely to agree that CS was rather about know-how than concepts and notions. However, the small sample size of that group makes these results subject to caution.

Question 3. Teachers have an opinion of what the ideal format of CS teaching should be. We wanted to compare this ideal representation with the two course types that are currently given, namely, the complementary-option CS course (hereafter referred to as C_1) and the cantonal CS course (C_2). We thus asked respondents to indicate, for each of these items, whether they completely disagree, somewhat disagree, somewhat agree, or completely agree with it—once for C_1, once for C_2.

"CS teaching in the context of this course...

1. is mainly about learning how to use office software" (Office)
2. builds on concepts and notions" (ConceptsNotions)
3. consists mostly of know-how" (KnowHow)
4. is given with a computer rather than with paper/pencil" (WithComputer)
5. mainly has the purpose of teaching tools useful for the students' work" (MainlyTools)
6. gives a representative overview of what the academic discipline is" (BigPicture)

We then asked a similar question: "Ideally, CS teaching in high schools..." with the same six subquestions as mentioned above, in a "should" form (i.e., item 1. becomes "should mainly be about learning how to use office software," 2. becomes "should build [...]", etc.). We refer to this hypothetical ideal course as C_0 and compare the responses to those given for C_1 and C_2.

The results are shown in Fig. 3. Looking at the C_0 bars, we can say that for about 80 % of respondents, a CS course in high school does not concern itself with teaching how to use office or other software tools. It should build on concepts and notions that do not systematically require the involvement of a computer, and provide a representative overview of the discipline. Respondents are split on the KnowHow subquestion, with about 57 % only agreeing that an ideal CS course should mainly consist of know-how.

In an effort to better visualize the differences between the ideal case and the two course types currently given, we performed a principal component analysis (PCA, see e.g. [1]) of these answers. The scree plot of the PCA is shown in Fig. 5, and the answers, divided into three groups, are shown along the first two principal components in the scatterplot in Fig. 4. The projection of the 6 initial dimensions have been overlaid on the scatterplot in order to better understand the nature of the principal components.

The scree plot shows the large importance of the first component, while the first two explain almost 80 % of the variance. This gives us confidence in the faithfulness of the scatterplot representation, on which the three groups of points are quite clearly separated. The C_1 and C_2 groups are even linearly separable. The former has negative values along the first component, corresponding to a teaching oriented towards concepts and notions and an overview of the discipline; the latter is strongly oriented towards office and other software tools and know-how. Both have positive values along the second component, which translates to these courses being very often given in computer rooms, in interaction with hardware.

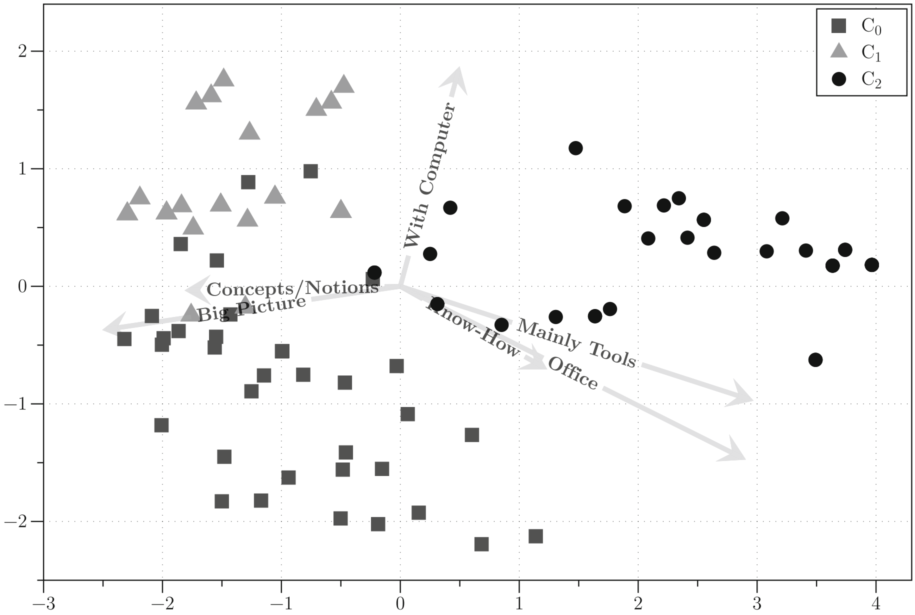

Fig. 4. Scatterplot of the first two components of the data shown in Fig. 3.

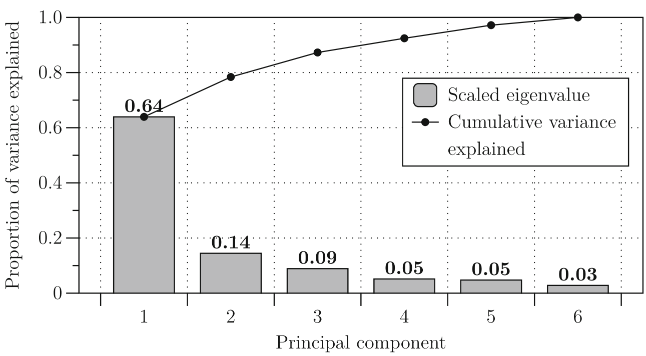

Fig. 5. Scree plot of the PCA whose first 2 components are shown in Fig. 4.

The comparison to the data points from the ideal group C_0 is interesting. A first observation is that C_1 is closer to the ideal course than C_2, but nevertheless, C_0 has a wider spread along the first component. Second, the most striking difference between C_0 and C_1 is along the WithComputer axis, indicating a tendency to consider that some part of CS teaching, contrary to what is being done now, should be done with paper/pencil. Roughly spoken, the ideal course focuses on the concept and notions like the C_1 optional course does now, but with a bigger emphasis on the know-how, and with a portion of it given outside the computer rooms.

Regardless of the distance between their ideal representation and the courses they are actually giving, respondents have a positive feeling towards CS teaching. Only one out of 37 respondents indicated being not satisfied with it, all others being either somewhat satisfied, satisfied, or very satisfied. 15 respondents (41 %) would like to teach CS more and only one would like to teach CS less (the others [21 people, 57 %] are satisfied with the current situation). Moreover, 92 % (33 out of 36) find it somewhat opportune, opportune, or very opportune for CS (as a science) to be taught to all students mandatorily.

Question 4. We wanted to know on what topics CS teachers needed continuing education. Two cases were distinguished: 1. the need for continuing education today in the context of the CS courses currently given (C_1 and C_2); and 2. the need for supplementary education that would arise if C_0 existed as a fundamental CS course for everyone (hereafter and in the legends referred to as "CS for all"). In the former case (today's situation), almost 90 % said they would need continuing education. In the latter, 79 % of those who said they would be interested to teach CS for all indicated they were likely to participate in a supplementary education program. Of those, nearly half (9 out of 21) said that they were even willing to participate in a program requiring about 300 hours of work (10 ECTS credits).

We are attached to a university for teacher education, and traditionally, we are not supposed to educate in matters related to the core discipline the future teachers will teach—only in matters of pedagogy and didactics. However, in certain fields, the need for courses with contents from the disciplines themselves is tangible. Thus, we first asked respondents to indicate the proportion of didactic aspects vs. aspects from the CS discipline they wanted to appear in the continuing education. The results, shown in Fig. 6, show that both now and in the hypothetical case of a future CS for all course, the continuing education courses offered to them should clearly not only consist of pedagogical aspects, but should review aspects from the fundamental CS discipline, too—and that even in a proportion slightly in excess of 50 %. This is interesting in two ways—fundamental scientific aspects are needed while pedagogical aspects are not dismissed as secondary or unimportant either.

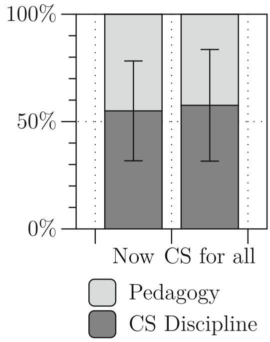

Fig. 6. Wanted breakup of continuing education related to CS.

Finally, we were interested in a list of topics for this continuing education that respondents would find most relevant and useful. Both for the current situation and in the case of a CS for all course, we asked them to grade topics as either unimportant, rather unimportant, rather important, and important. The number of respondents finding each topic at least rather important is shown in Fig. 7, with the topics being ordered according to the average awarded importance. The topics themselves are categorized in three groups, represented by different colors:

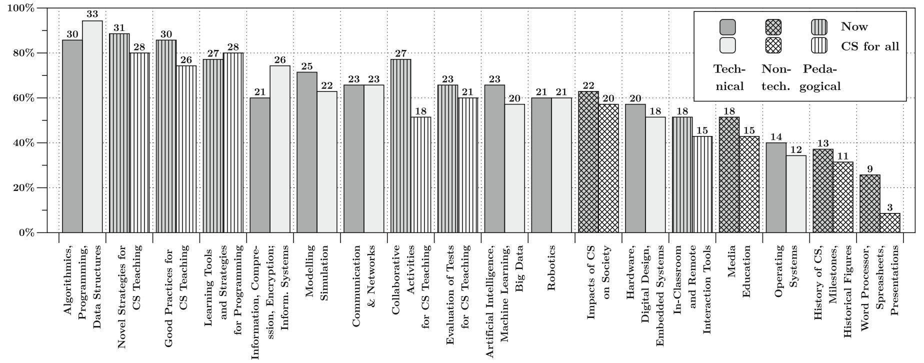

Fig. 7. Proportion of respondents who find the list of shown topics important in their continuing education as CS teachers.

first, fundamental topics from core CS; then, less technical topics related to the interaction of CS with society and media; and finally, topics linked to pedagogy and didactics.

A first observation is that the importance of topics is quite stable in the two distinguished cases. When considering the difference in awarded importance between the "now" and "CS for all" cases, we note a small, but statistically significant increase in importance for the group of core CS topics at the expense of the other two groups ($H(1) = 3.07$, $p = 0.079$). These results still give us a strong basis for the planning of continuing education courses today whose structure will still be relevant if and when CS for all is introduced.

We see that Algorithmics, Programming, Data Structures is the theme deemed most important, followed by three pedagogically oriented themes. Among the more technical themes, we can also observe that more importance is awarded to the fundamental themes (like programming, communication, representation of information) than to the more applied themes (like machine learning, robotics, operating systems). It remains an open question to know whether this is due to the fact that the respondents feel that the applied themes are less important in the context of their teaching, or that they feel they are more easily able to catch up on their own on such applied themes.

Then, whether we take the first 2, 6, 8, or 10 topics according to their awarded importance, we exactly have half of them belonging to the CS discipline and half of them treating pedagogical aspects, qualitatively reiterating the results from Fig. 7: the proposed continuing education should definitely not exclusively focus on pedagogical aspects to be of interest to the respondents.

5 Conclusion

We described the current state of CS teaching in Swiss high schools as well as some of the intricacies that led to it. Starting from that, we exposed our research questions, which we investigated with a survey sent to CS teachers from the French-speaking part of Switzerland.

The major results from our survey showed that most teachers currently do not have a primary education in CS, although the proportion in increasing. Most of them, however, had some form of complementary education in CS-related topics.

Regardless of their background, the respondents' view of what CS is does not differ fundamentally along the dimensions we explored, even if those with no CS education were less likely to have strong opinions on the nature of the field.

The representation of the ideal CS course, which gathers a strong agreement among respondents, differs from the two course types that are currently offered. The current offerings consist of a cantonal course, which is deemed as too focused on the usage of some software tools and not focused enough on concepts and notions, and of an optional course, which is closer to the ideal representation of the ideal CS course—one major difference being that the ideal course should include a more important part of pencil/paper activities and happen less often in front of a computer.

Finally, respondents indicate strong need for continuing education with a balanced proportion of both pedagogical topics and topics linked to the fundamental aspects of CS.

Our survey was only run on the French-speaking part of the country: it would be very interesting to extend this study to the German-speaking part of Switzerland, too, and to look into the causes for potential significant differences.

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