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# **Evaluation of the international Master's programmes: Computer Science and Bioinformatics**

Helsingin yliopisto  
Tietojenkäsittelytieteen laitos





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## **ABSTRACT**

The Department of Computer Science at the University of Helsinki started recruiting students to the Master's programmes from abroad so that the first set of foreign students started at the beginning of the 2010 autumn term. In autumn 2010 18, 2011 23 and 2012 23 foreign Master's students started at the department. In addition two students started in the spring terms. In this report we follow the study success of these students and seek reasons for varying study success. We compare the study success of foreign students to the study success of domestic students who completed their Bachelor's degrees at the Department of Computer Science, University of Helsinki.

We describe the application procedure, the origins and numbers of applicants and selection processes and criteria. Reception of students and introducing them to the local study culture play an important role in a good start of studies. We describe our efforts to smooth out the initial stages.

The Master's programme in Bioinformatics and Cross-Border University Master's programme in Information and Communication Technology have started earlier and are international. We present briefly the study success of their students.

Finally we suggest actions for further consideration to make the Master's programmes more successful for students and the department.

The main findings include the observation that students with previous training that differ from UH Bachelor's degree requirements are likely to fail courses more often than students with training more similar to UH requirements. Among foreign students the variation in study success seems to be larger than among domestic students. Cultural differences in scientific writing must be addressed carefully and also differences in self-directions of students are substantial.

## CONTENTS

1. ASSIGNMENT DEFINITION AND DESCRIPTION OF INVESTIGATION .....	5
1.1 Definition .....	5
1.2 Data from OODI .....	5
1.3 Application documents and other background material .....	6
1.4 Query forms .....	6
2. APPLICANTS .....	6
2.1 When and how to apply .....	6
2.2 Numbers of applicants and starters .....	7
2.3 Country of origin and country of residence .....	8
3. STUDY PROGRESS .....	9
3.1 Earning course credits .....	9
3.2 Study success .....	12
3.3 Progress and Bachelor's degrees .....	17
3.4 Students in the Master's programme in Bioinformatics .....	19
3.5 Students in the CBU Information and Communication Technology programme .....	20
3.6 The students' own experiences of their study progress on the basis of the query .....	21
3.7 Teacher experiences on performing the courses .....	21
4. SUGGESTED ACTIONS .....	23
ACKNOWLEDGEMENTS .....	25
APPENDICES .....	26
A. SELECTING STUDENTS .....	26
A.1 Marketing the Master's programmes annually .....	26
A.2 The annual selection process .....	26
A.3 Annual admission criteria .....	27
A.4 Students' reasons for applying .....	28
B. RECEPTION OF STUDENTS .....	29
B.1 Before arrival .....	29
B.2 Orientation on arrival .....	29
B.3 Integration into student community .....	30
B.4 How the students experience their orientation .....	30
C. INTRODUCING STUDENTS TO THE STUDY CULTURE OF THE DEPARTMENT ....	31
C.1 Student counselling .....	31
C.2 Scientific writing .....	31
C.3 Complementary courses .....	32
C.4 Proficiency and courses in Finnish and English .....	32
D. SURVEY FOR MASTER PROGRAMME STUDENTS OF CS DEPARTMENT .....	33
E. KYSELY OPETTAJILLE KANSAINVÄLISISTÄ MAISTRIOHJELMISTA .....	36

# 1. ASSIGNMENT DEFINITION AND DESCRIPTION OF INVESTIGATION

## *1.1 Definition*

This report describes and evaluates the course and success of the Master's programmes at the Helsinki University (UH) Department of Computer Science. Special attention will be paid to the department's application processes for two international programmes and how well the international students do in their studies, while looking for factors that might have improved or impaired the students' progress. The Master's programmes that we are looking at are Algorithms and Machine Learning (AlMa), as well as Networking and Services (NeSe).

The teaching in these two programmes has been completely given in English since the department extensively started recruiting students for the Master's stage from abroad; the first set of foreign students started at the beginning of the 2010 autumn term. This report focuses on the foreign students that started in autumn 2010 through autumn 2012. For the sake of comparison we also present the study success of domestic Master's students who proceeded from their Bachelor's studies to Master's studies in the same period.

We will also take a look at the success of students in the Bioinformatics and the Cross-Border University Information and Communication Technology (CBU-ICT) programmes. The last new students accepted into the CBU-ICT programme started in autumn 2011 and no new students will be accepted later.

## *1.2 Data from OODI*

Students who had started their Master's programme at the department or in Bioinformatics in autumn 2010 or later were isolated from the OODI study credit registry. Students from abroad who had taken their Bachelor's or corresponding degree somewhere other than the University of Helsinki, and who had not taken any other course at UH, were included. These students were accepted into UH either through the international admission process (see [http://www.helsinki.fi/facultyofscience/studies/apply\\_cs.html](http://www.helsinki.fi/facultyofscience/studies/apply_cs.html)) or the separate admission process (<http://www.helsinki.fi/facultyofscience/studies/separateadmission.html>).

As a baseline in study success we used OODI data of domestic students who had completed their Bachelor's degrees at UH and started their Master's studies in the period of this report.

The OODI data is from around 12 August 2013.

### *1.3 Application documents and other background material*

The application documents of foreign students described in 1.2 were analysed and the information that was deemed pertinent was picked out.

In addition, the taskforce had at their disposal earlier query answers from students from two year's time. The queries had been given to the students after their first week and after their first study period. This gave us 'authentic' descriptions and experiences from the students of the very beginning of their Master's degree work.

### *1.4 Query forms*

The taskforce implemented new queries as e-forms, both to the students and their primary teachers. The forms are attached to this report.

The query was sent to all international students who had started their Master's programmes in Computer Science (including CBU-ICT) or Bioinformatics in autumn 2010 or later – including those who had already passed their degree. The only requirement was that their email address was in OODI. Students who are no longer registered with UH do not have a UH email account. The query was sent to 102 students and we received 31 replies (30%).

The 30 teachers of Master's courses received the query and half of them (15) replied.

## **2. APPLICANTS**

### *2.1 When and how to apply*

The new international students for the Master's stage at the faculty either come through (1) the international or (2) separate application process. The international application acceptance period typically ends at the end of January, and the application deadline for separate selection is at the beginning of April and October.

International applicants are defined as persons who have attained their lower university degree in another country than Finland and who have completed a suitable degree with good grades. In addition it is required that applicants have the necessary skills in Finnish, Swedish or English, and that the contents and scope of their degree is sufficiently equivalent to the Bachelor's degree in the science field they are applying for.

In the separate admission every spring and autumn, Master's programme entry is accorded on the basis of a suitable degree from a university of applied sciences or a university in Finland. The admission is based on the grade level (grade point average, GPA, at least 3.8/5 in the main subject) and applicability of the previous degree, as well as the applicant's study plan.

## 2.2 Numbers of applicants and starters

There are annual statistics on the international application process, but not on the separate application process.

Year	Starters	Approved	Department applications	UAF applications
2010	15 + 3 + 5	47	196	268
2011	14 + 9 + 3	62	266	421
2012	20 + 3 + 0	48	199	363

Table 1. Statistics on international applications. The applicants to the Bioinformatics or CBU-ICT programme are not included. UAF applications are paper applications received by University Admission Finland (UAF). UAF sends formally acceptable applications to the department for further consideration. Starters are students who came through the international application process + separate admission + CBU-ICT.

Two students started at the beginning of the spring terms.

### 2.3 Country of origin and country of residence

In the years 2010 – 2012, there have been applications from some 60 countries with the same number of different nationalities among the applicants. Tables 2 and 3 list the countries with over 5 applicants.

Country of origin	Total	2010	2011	2012
China	138/25	54/9	53/6	31/10
India	122/4	41/0	37/0	44/4
Pakistan	98/3	21/1	45/2	32/0
Iran	72/7	10/0	43/4	19/3
Bangladesh	37/5	10/2	14/2	13/1
Nepal	26/1	8/0	11/1	7/0
Nigeria	17/1	7/0	7/0	3/1
Ethiopia	16/3	7/3	3/0	6/0
Russia	13/4	4/2	4/1	5/1
Turkey	10/1	2/0	4/1	4/0
Vietnam	7/2	1/0	2/0	4/2

Table 2. Most common nationalities among applicants/starters. Starters include students that were accepted in the separate admission.

Country of residence	Total	2010	2011	2012
India	122	39	39	44
China	118	44	50	24
Pakistan	74	17	38	19
Finland	65	39	11	15
Iran	64	11	39	14
Bangladesh	30	7	10	13
Nepal	23	6	10	13
Sweden	23	1	9	13
Russia	12	3	4	5
Turkey	10	2	4	4
Malaysia	9	2	2	5
Ethiopia	6	2	0	4

Table 3. Countries from which the most applications have been sent.

Nearly all BSc graduates who entered the Algorithms or Networks programmes came from different universities. Foreign students from Finnish universities of applied sciences have mostly come from Turku or Rovaniemi.

### 3. STUDY PROGRESS

#### 3.1 Earning course credits

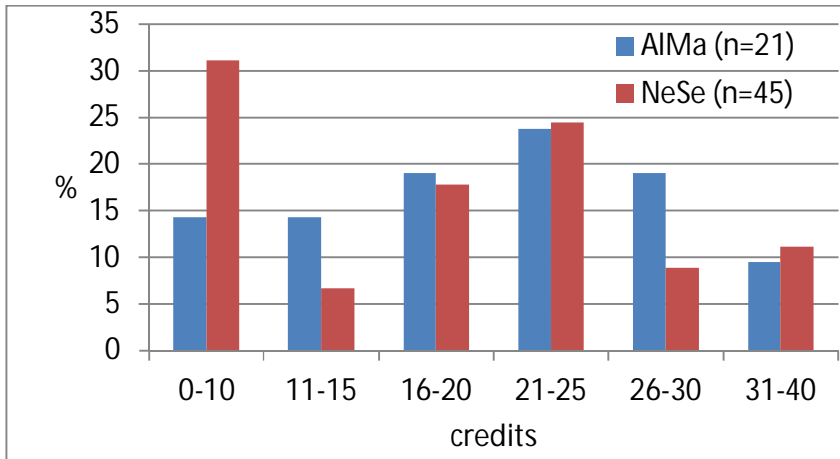


Figure 1. Number of credits during first semester (AIMa = Algorithms and Machine Learning and NeSe = Networking and Services).

For students to finish their Master's degree in the stipulated two years (= four terms), they should complete an average of 30 credits per term. This number or close to it (>25 credits) is attained by 29% of the Algorithms students and 20% of the Networks students (figure 1). It is especially the Networks programme that is encumbered with a set of students (31%), whose studies did not progress much during their first term (figure 1).

Of the stipulated 30 credits, 38% of the Networks students and 29% of the Algorithms students reached only half or less (figure 1).

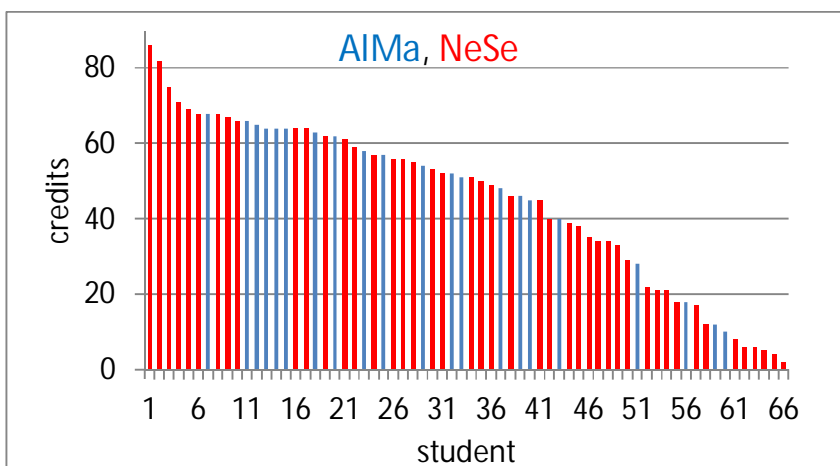


Figure 2. Sum of credits from first and second term.

For the department, the funding model makes it most beneficial if as many students as possible gain at least 55 credits per year. Figure 2 shows that 28 (42%) of the Algorithms and Networks students reached this goal during their first year.

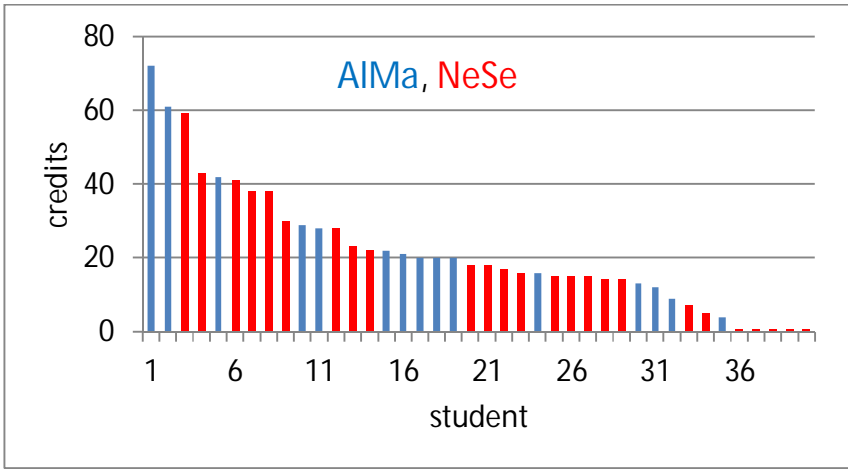


Figure 3. Sum of credits from the third and fourth term.

During their second year, only 3 students reached the goal of at least 55 credits, because only a few students finished their Master’s thesis before the end of their second year.

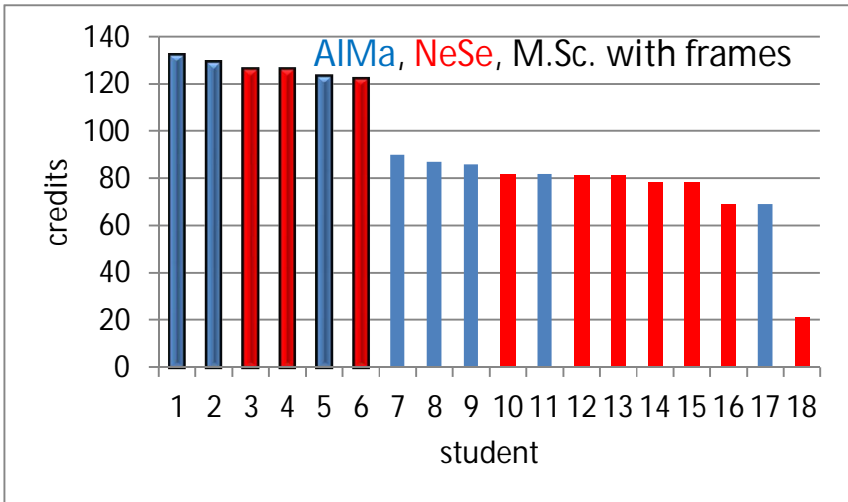


Figure 4. Total of credits gained by students who started in autumn 2010, in three years.

At the beginning of autumn term 2010, 18 international students entered the Algorithms and Networking programmes. After 6 terms, 6 have completed their Master’s degree, and 7 have started their thesis work (as per thesis database), and the 5 students left are still taking courses.

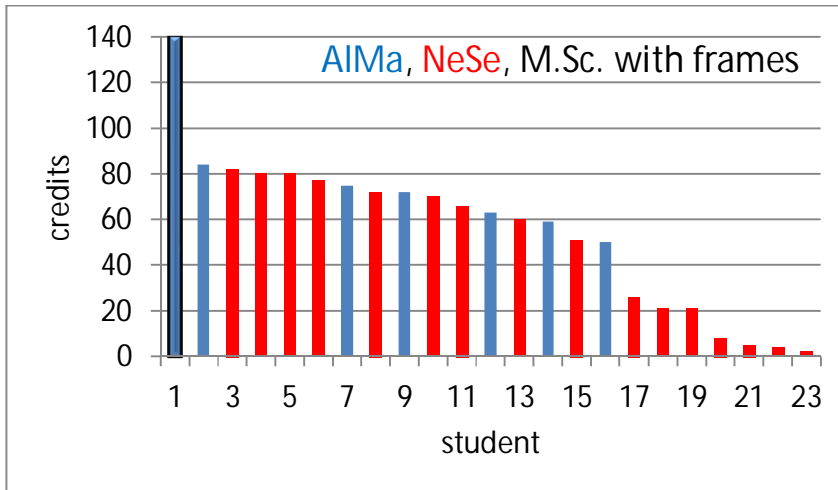


Figure 5. Total of credits gained by students who started in autumn 2011, in two years.

At the beginning of autumn term 2011, 23 international students entered the Algorithms and Networking programmes. After four terms one has completed her thesis work and two have started their thesis work. Three students have registered as absentees, and three students have been removed from the registry. Most of the students (17) are taking courses. In four terms 10 students (43%) have gained less than half (<60 credits) of the stipulated number of credits (=120 credits).

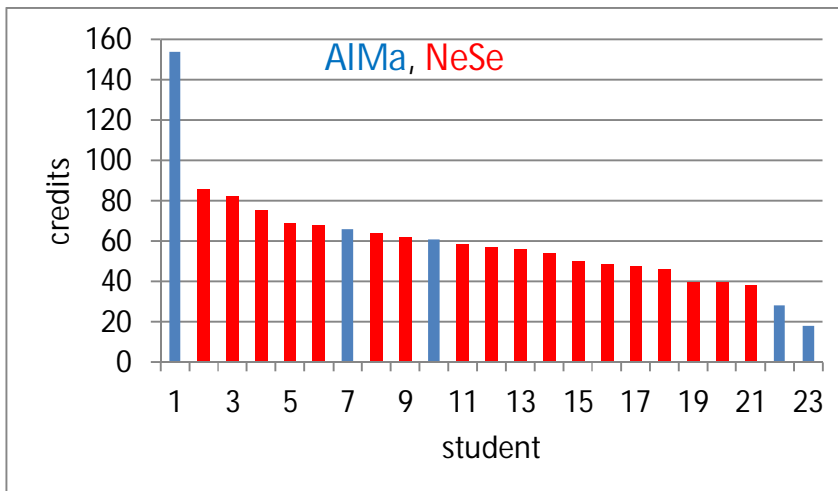


Figure 6. Total of credits gained by students who started in autumn 2012, in one year.

At the beginning of autumn term 2012, 23 international students entered the Algorithms and Networking programmes. Out of these, 13 students have gained at least 55 credits in one year. Two students have gained less than 30 credits.

If we compare the graphs of credit sum distributions for students who have started in autumns 2010-2012, we can see that they are similar, but the graph for students who started in 2011 contains more students who only gained a few credits.

### *3.2 Study success*

The success of the students' work was measured according to the ratio of passed and failed Computer Science courses. In addition to passed grades, the failed attempts are entered into the OODI credit system. A failed exam or course performance is included in the failed courses, no matter how actively the student has attended the course or exam. At the very least, the student has signed up for the exam but never showed up. On the other hand, a student who has taken active part in a course but removed themselves from the ILMO registration system right before the course results are registered will not be registered in OODI as a failed attempt.

As the index for study success we used the percentage of passed Computer Science courses out of the sum of passed and non-passed Computer Science courses, weighted by the number of credits. The index is 100 if a student has completed and passed all attempted courses and 0 if all attempts have failed.

We compared the course success of the international students to the success of domestic students who started their Master's studies in the same terms as the international students. The domestic students accomplished their Bachelor's degrees in UH.

We can consider the course work to be going well if at least three quarters (course success index  $\geq 75$ ) of the attempted courses lead to a passing grade.

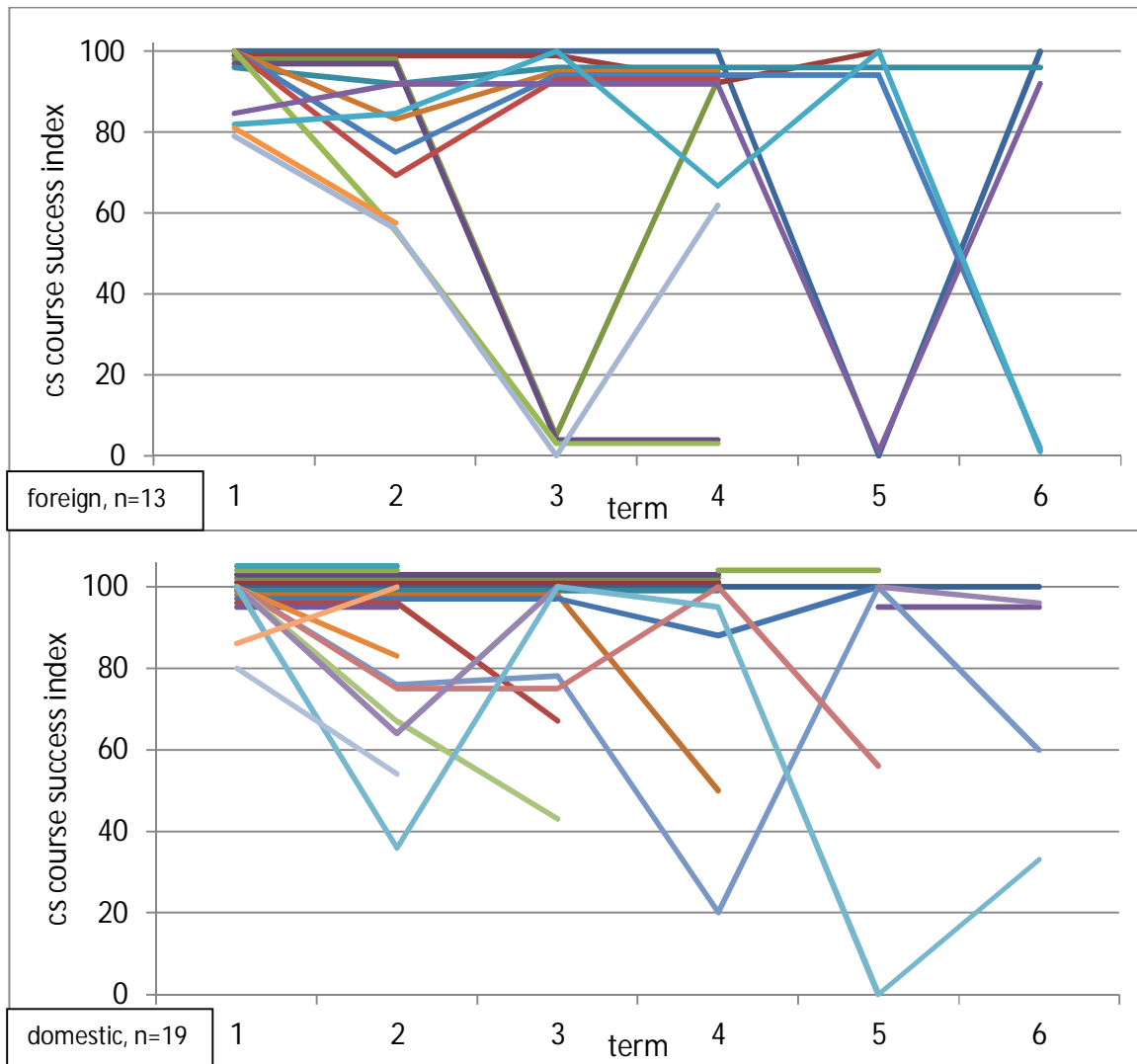


Figure 7. The success of Algorithms and Machine Learning students in Computer Science courses per term from the start of their studies. These students attained index 75 or more in their first term. Foreign students top (n = 13) and domestic students bottom (n = 19).

There are more domestic than foreign Algorithms and Machine Learning students who performed excellently in their Computer Science courses. After two or three terms successful students usually have completed most of their courses. Some students can be considered as half-day students because they are also working during terms and their studies can be prolonged. However, in later terms the students usually take only one or two Computer Science courses and dropping a course can cause the variation of success index in later terms (figure 7).

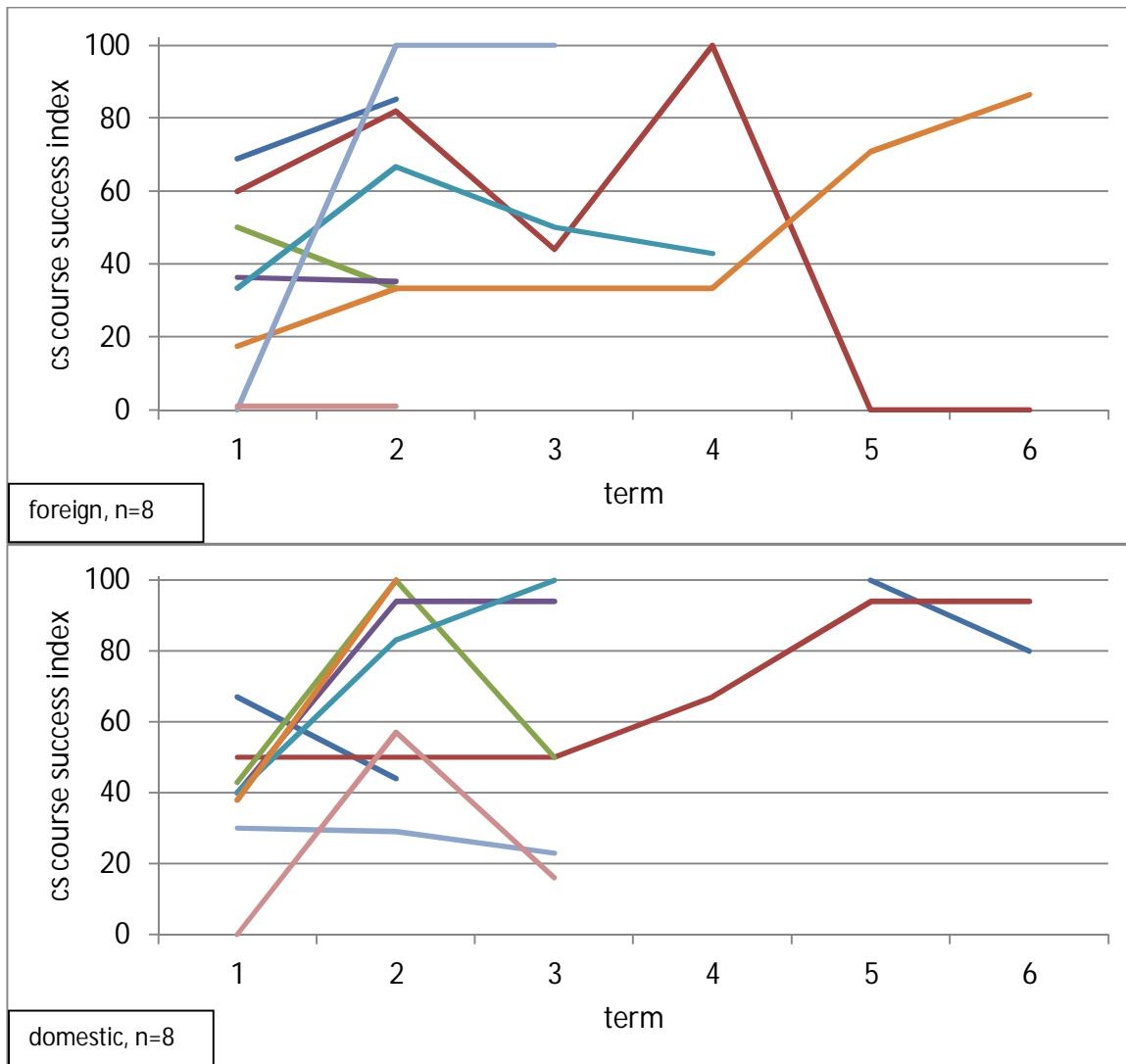


Figure 8. The success of Algorithms and Machine Learning students in Computer Science courses per term from the start of their studies. These students attained an index of less than 75 in their first term. Foreign students top (n = 8) and domestic students bottom (n = 8).

Students who did not start excellently usually later perform excellently only in single terms (figure 8). Among Algorithms and Machine Learning students a bigger proportion of domestic students seem to start off well (success index  $\geq 75$ ) than that of foreign students (figures 7 and 8). The well starting groups in both foreign and domestic Algorithms and machine learning students are bigger than the less well starting groups (figures 7 and 8).

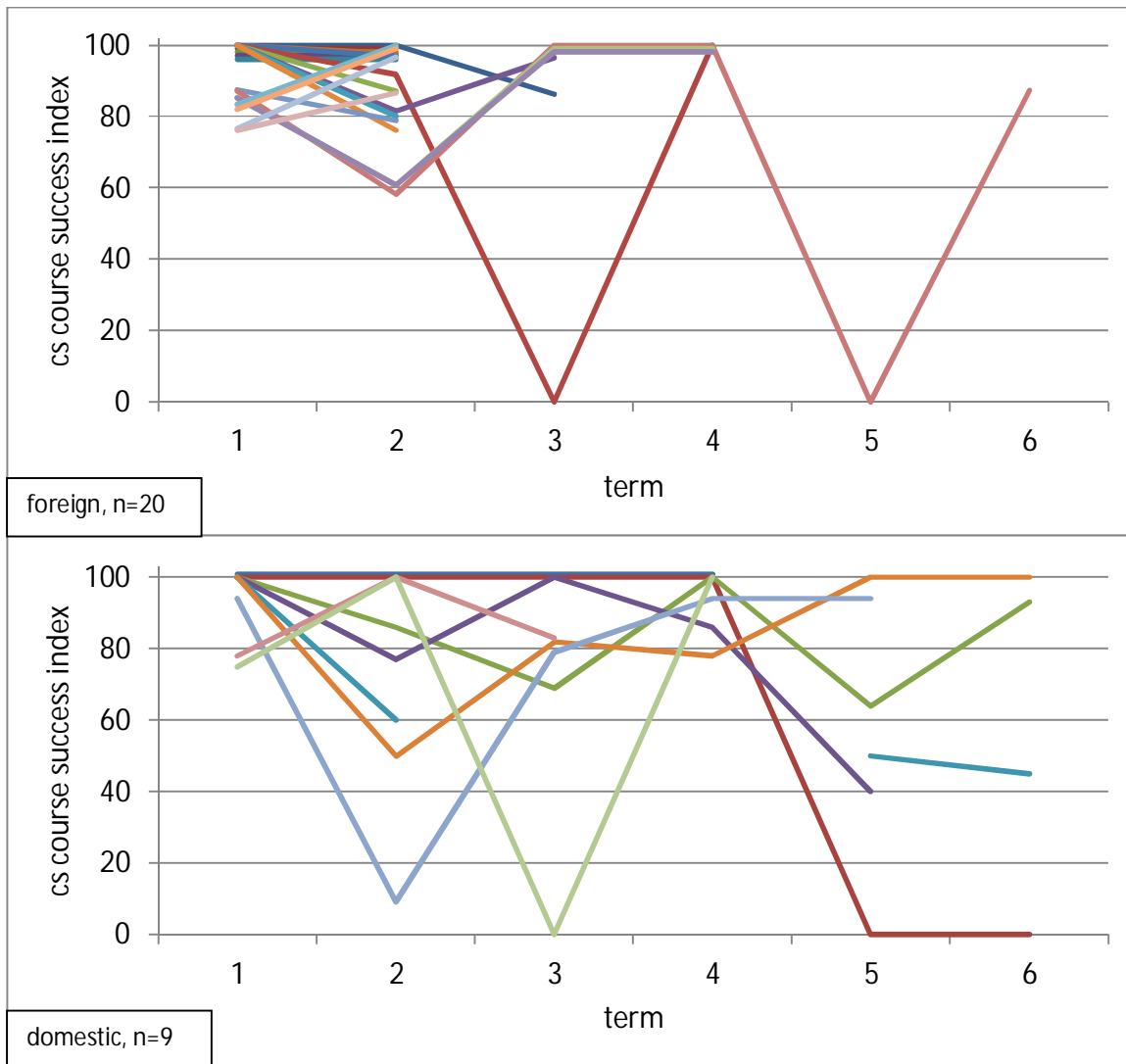


Figure 9. The success of Networking and Services students in Computer Science courses per term from the start of their studies. These students attained an index 75 or more in their first term. Foreign students top (n = 20) and domestic students bottom (n = 9).

Many foreign Networking and Services students who started in autumn 2012 (studied two terms) performed very well in their studies (figure 9) whereas fewer students from previous cohorts started well. The Computer Science course success indices of both foreign and domestic students are similar during the three first terms where the comparison is reasonable (figure 9).

Especially students that started their studies well seem to have experienced a slump in their second term. This applies to both Algorithms (figure 7) and Networking (figure 9) students.

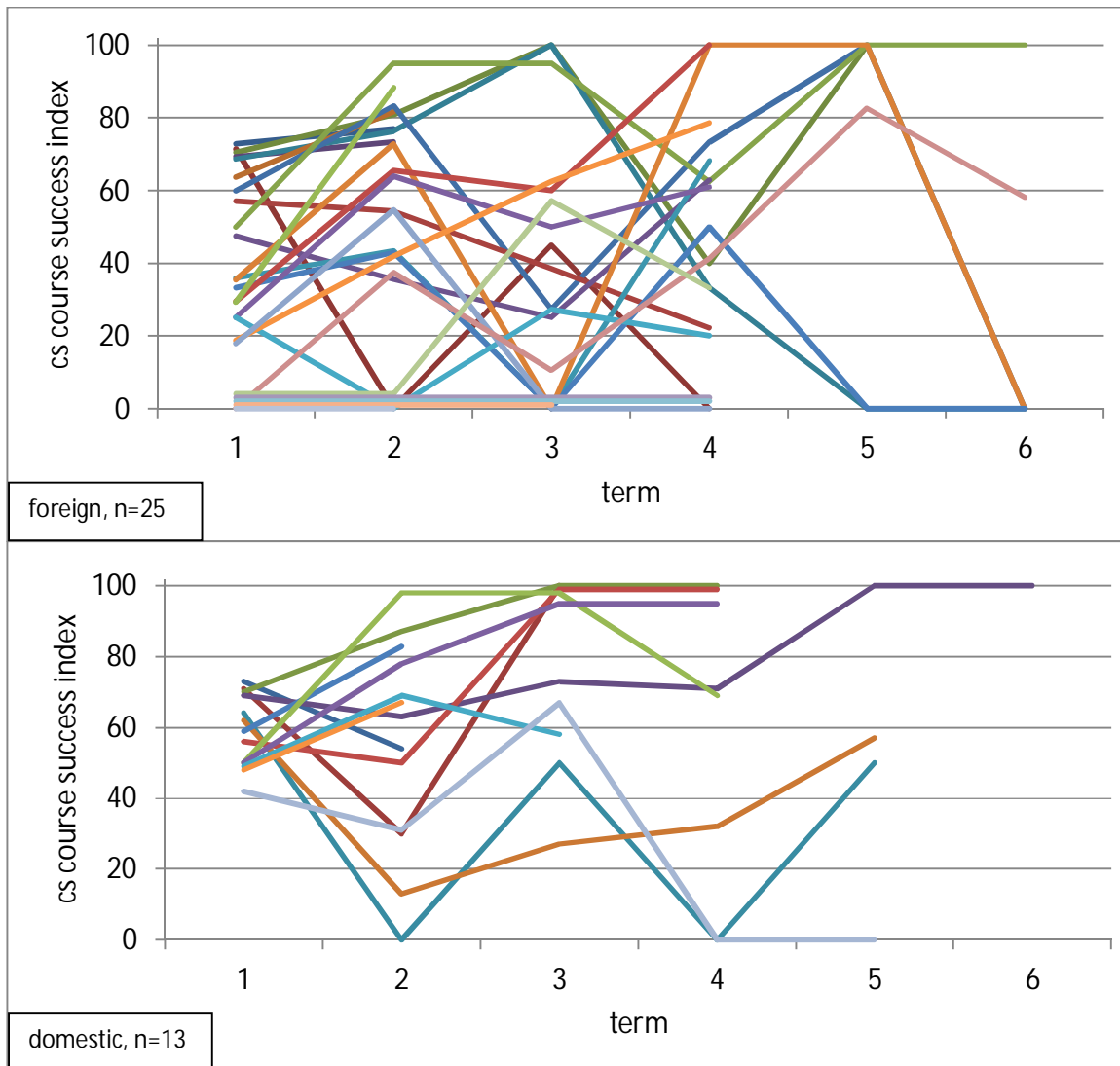


Figure 10. The success of Networking and Services students in Computer Science courses per term from the start of their studies. These students attained an index of less than 75 in their first term. Foreign students top (n = 25) and domestic students bottom (n = 13).

Students who in their first term failed more courses than they passed are likely to keep having difficulties also later (figure 10 foreign students). Only in their fourth or later terms some of them improve significantly. The well starting groups in both foreign and domestic Networking and Services students are smaller than the less well starting groups (figures 9 and 10). The variation of Computer Science course success among foreign Networking and Services students is large.

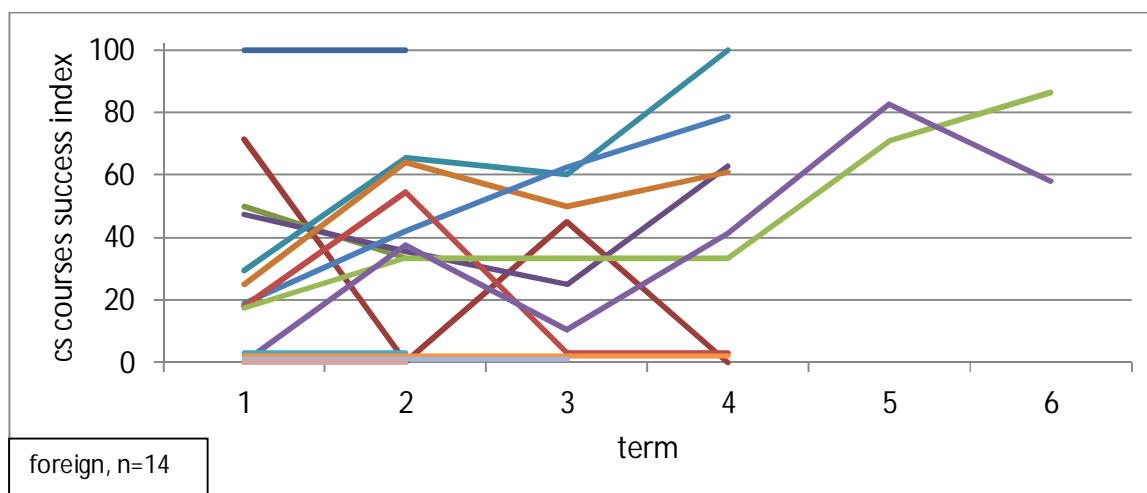


Figure 11. The success of students from universities of applied sciences (n=14) in Computer Science courses per term from the start of their studies.

Out of students from universities of applied sciences, 11 are in the Networking and Services and 3 in the Algorithms and Machine Learning programme. Only a few students from universities of applied sciences have started their studies well and continued well.

### 3.3 Progress and Bachelor's degrees

Each student's application was scrutinized for similarities between their previous studies and the BSc degree at the UH Computer Science department according to seven different skill criteria:

1. Programming and software engineering.
2. Databases.
3. Data communications.
4. Data structures and algorithms.
5. Operating systems.
6. Computer organisation.
7. Computer Science theory (like computational models).

Students received 0 points for each item if we could not find any connection to the area in their course credits, or one point if it seemed to be part of their course credits, so each student could receive 0-7 'similarity points'.

It is worth mentioning that some of the students had not yet finished their BSc degree when they filled in the application forms, so they may not have received enough points in comparison with the situation when they started at UH. On the other hand, they would not have had time to learn many new areas of Computer Science after the application deadline. We did not check at all the correspondence between the name and contents of courses completed in different parts of the world. We could not determine the quality of the courses or learning any more exactly than as far as course credits went. If we would try to foresee study success on the basis of the applications, we can only use the information in the applications. It is not realistic to start investigating the contents of tens or hundreds of thousands of separate courses.

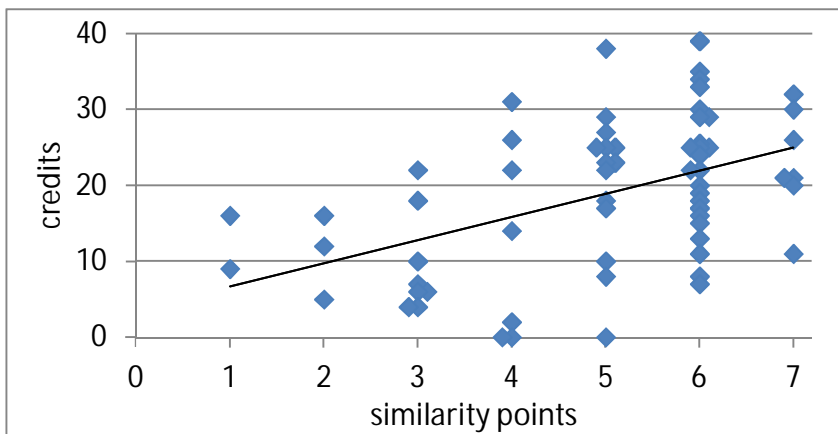


Figure 12. The sum of credits in the first term and their relation to the applicant's previous degree. The larger the similarity index (0-7) is, the closer the student's previous studies are to the UH Bachelor's degree in Computer Science. The linear trendline is shown.

Figure 12 shows us that all the students, whose similarity index is 3 or less, have attained less than 25 credits during their first term, while out of students with index 4, only 2 have gained over 25 credits during their first term. Though the dispersion is large at each index, we can state that students with a higher index usually complete more credits during their first term than students with lower indexes.

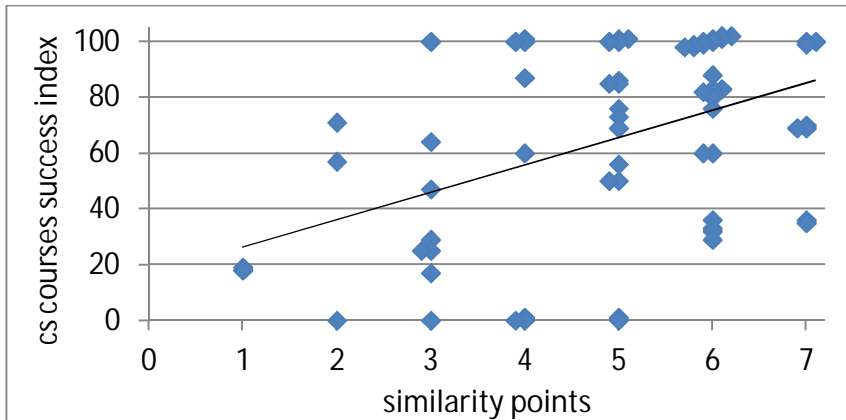


Figure 13. Interdependency of success index in first term of Computer Science studies and the similarity index of previous studies. The larger the similarity index (0-7) is, the closer the student's previous studies are to the UH bachelor's degree in Computer Science. The linear trendline is shown.

Figure 13 shows us that the percentage of passed courses in Computer Science is lower with lower similarity point values and better with higher values. It is a similar phenomenon as the interdependency of gained credits and similarity points shown in Figure 12.

### 3.4 Students in the Master's programme in Bioinformatics

In autumn 2010, six international students entered the Master's programme in Bioinformatics. Five of them have graduated Masters and the sixth has gained 80 credits. In autumn 2011, five international students entered the programme, and six in autumn 2012.

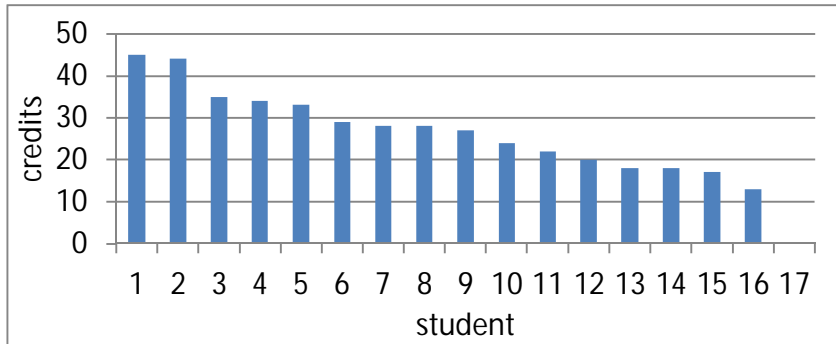


Figure 14. Sum of credits gained by international students in the Bioinformatics Master's programme during their first term.

Figure 14 shows that nine (53%) students had gained at least nearly the stipulated number of credits (>25) during their first term. Only one student did not get started at all.

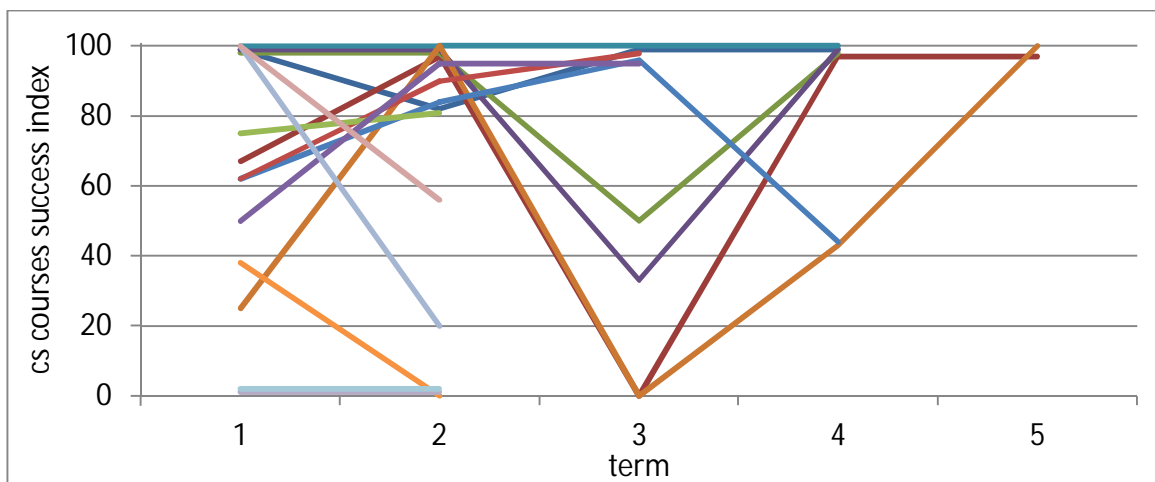


Figure 15. The success of Bioinformatics students (n=17) in Computer Science courses per term from the start of their studies.

The principle of Figure 15 is described in 3.2. The Bioinformatics students usually do well in their Computer Science courses, either from the start or after their first term. In the third term and later, they do not attend many Computer Science courses any more. This means that dropping out of one, maybe the only, course makes a big difference in the course success index.

### 3.5 Students in the CBU Information and Communication Technology programme

In 2010, five students entered the CBU-ICT programme, two of whom had completed a Master's degree. In 2011, three students entered the programme, and in 2012, the programme did not accept new students any longer.

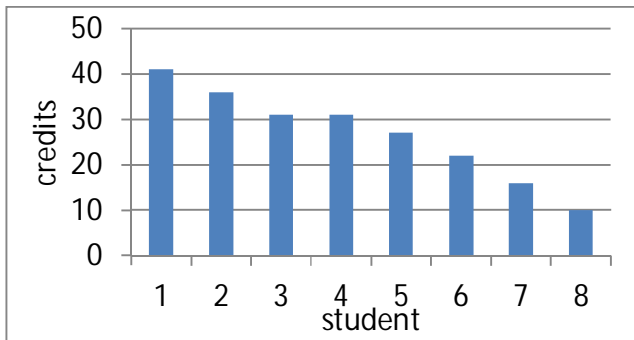


Figure 16. Total credits gained by international students in the CBU-ICT programme during their first term.

Figure 16 shows that five students had gained at least nearly the stipulated number of credits (>25) during their first term. The other students also commenced their studies.

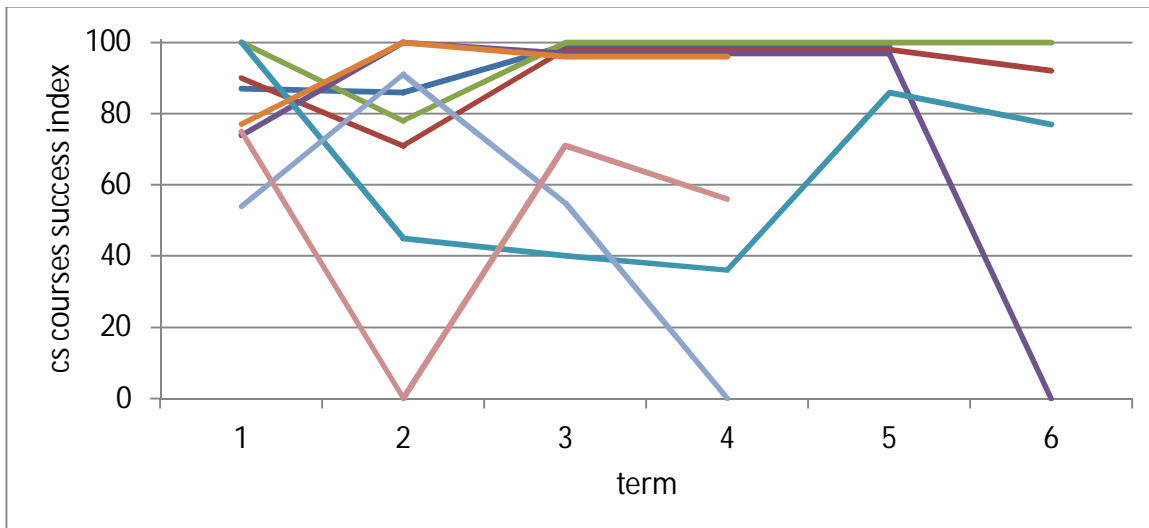


Figure 17. The success of CBU-ICT students (n=8) in Computer Science courses per term from the start of their studies.

The principle of Figure 17 is described in 3.2. The students in the CBU-ICT programme have mostly done well in their Computer Science courses.

### *3.6 The students' own experiences of their study progress on the basis of the query*

The students gave more positive feedback about the instruction than the orientation. Many thought that the course in scientific writing was good and useful.

The studies have progressed fairly well in relation to the students' own expectations. Some students mentioned that their studies were impaired by their lack of background knowledge due to e.g. lack of suitable courses, the difference in background (e.g. natural science) in the BSc degree or a different background in e.g. probability calculus theory. The problems with adapting to a new culture and course structure were also mentioned as impediments.

Theoretically based and mathematical courses were experienced as very challenging. One student thought nothing was easy, and especially the assumptions about his skills were not realised when it came to his BSc degree. As examples he mentioned the knowledge of a certain programming language and the basics in mathematics.

Having to work during terms was mentioned as an impediment. Out of 31 students, 13 worked 20 hours or more each week during terms, and five worked practically fulltime (>30 hours per week). In relation to how common it was for students to work, there were not many mentions of the clash between studying and working. Most of the students who had a job said that their work was related to their studies, with one fulltime and one part-time worker, whose jobs had nothing to do with their studies. There were more working students in the Algorithms and Machine Learning programmes, and fewer in the Networking and Services programme and the Master's Degree Programme in Bioinformatics.

The students' expectations of finding a job after they graduate were tinged with some insecurity. However, over half of them set their job expectations on the positive side of the scale.

### *3.7 Teacher experiences on performing the courses*

The instructors' assessment of the skill level of the foreign students in the Master's programmes in relation to students who have taken their BSc degree at the department, especially with respect to completing courses, centres around the middle of the scale with some weight on the negative side. Their assessments of how the students do in the Master's programmes also settle around the middle, but are clearly more centred on the positive side of the scale.

The general level and background knowledge of the students vary, as does their motivation. One instructor stated that it was pointless to assess the students on a scale of 1-7 because of their heterogeneity. The best among them are potential postgraduates, but there are students among the weaker ones who do not seem to have any realistic idea of what they need to know. Some seem to want a degree without putting much effort into learning, at least not on their own initiative.

In general, the students are considered to have 'hard going times every now and then.'

'On an average, the students' knowledge and skills seem to be at the department's BSc level. However, the focus may be different from what we assume.'

The instructors were asked about the English proficiency of all the students, as well as the Finnish skills of the foreign students. One in three instructors thought that the foreign students had poor English skills, but only one instructor thought Finnish students had a poor grasp of English. One instructor thought the foreign students were proficient enough in Finnish, while two out of three thought their knowledge of Finnish was very poor.

The instructors describe the international students as follows:

- “[MSc students] in comparison with department BScs are, to generalize: more hard-working, less proficient in languages, more passive, more obedient.”
- “Some do very well (a minority), most of them are average, some are hopeless.”
- “Most of the students in the Master’s programmes are motivated and eager to complete courses quickly. Many also want good grades, but their skills do not always warrant the grade levels they wish for. [...] In terms of skills, the largest differences seem to exist between nationalities [...] In terms of their skills, the whole population of the Master’s programmes is equivalent to the Finnish students.”
- “The students in Master’s programmes work more intensively on average, and question the instructor more.”
- “The skill levels are very varied. However, there are less of the completely passive students.”
- “The enthusiasm is often evident. The students also consider the teaching material critically, and ask questions during the lecture if they don’t understand.”
- “[Background in university of applied sciences]... it seems to be more of a mystery to them, what the Master’s programme is all about.”
- “Students with a degree from a university of applied sciences have more problems on average than those with a foreign Bachelor’s degree.”

Several replies mentioned the different attitudes to plagiarism among the students as a specific problem. In spite of our efforts, it has proved hard to fix.

“There are huge deficiencies in written presentations, both for some Finnish students and some foreign ones. The main problem is that, if the text that is handed in is mostly copied from other sources, it is hard to assess the writer’s own language skills. Teamwork also makes it harder to assess students, since the text may have been written by any member of the team. One important warning sign of a copied text is that the writing suddenly changes into text ready for publication.”

Some shortcomings that were mentioned include programming skills, the basics of operating systems (Linux, Unix), and statistics. In Bioinformatics, some were found not to know programming very well.

About teamwork, the instructors stated:

- “I’ve started to avoid giving students team assignments, since they always seem to lead to a situation where one student does all the work and the others copy it.”
- “The Chinese and the Indians, who don’t seem to be the best of friends, don’t like to communicate (can never be put in the same teams) since they don’t understand each other’s accents.”

Differences between ethnic groups:

- “In the Master’s programmes, you sometimes encounter the attitude ‘this is a university, why do I need to know how to program?’ (which I understand is the case in China).”
- “Russian students are often very knowledgeable in both theory and practice, and they’re often among the best in class.”

Academic writing: “Sometimes lacking in basic knowledge about academic writing. They are not familiar with presenting their own thoughts and argumentation.”

Language skills: “There have not been evident deficiencies in oral English skills.”

Other comments from the query forms to the instructors:

“If we want to keep the programme multi-disciplinary like this, our department must support the students with some kind of programming course in English in the same way as e.g. the Department of Statistics offers the course Introduction to Probability for students who do not have a background in statistics.”

“Whenever possible, we should pay more attention to quality in admissions. Students with poor previous knowledge or language skills should simply not be admitted, if there is any way to weed them out (which is, naturally, hard).”

“The department must improve its public presentation of the programmes it offers.”

“The department could also make a clearer distinction of whether the Master’s programmes are an extension of our BSc programme, or whether it will be developed into its own independent programme that can be completed by students coming from outside the department.”

“The admission criteria should be more exact, particularly so that they are based on studied data.”

#### **4. SUGGESTED ACTIONS**

We want to propose preliminary suggestions for further discussions. The suggestions are in no particular order.

1. International assessments have found that Finnish students are independent and mature compared to their peers around the world. The department has tried to meet this need with tutoring and orientation courses when international students arrive at the department. We still have to focus on introducing students to the learning culture at the department and emphasising their responsibility for their own learning when international students first arrive in order to integrate them into the Finnish learning culture immediately. We must be strict about this (e.g. cultural differences in writing essays) while respecting their background.

2. In admissions, we must concentrate more on analysing the similarities between the department’s BSc degree and the applicants’ previous courses. If the applicants’ previous studies are not fairly close to the department’s BSc degree, there is a risk that their work here starts weakly and

progresses slowly. It can be assumed that the life of a student in this situation in a foreign land would not be very satisfactory. If applicants' courses are very different from the department's BSc degree, we should seriously consider not admitting them. The applicants typically apply to several universities, and it might be safer for the students to continue on a learning path that might be more suitable for them.

3. We have reason to tighten the criteria for admitting international students from Finnish universities of applied sciences (UAS). There are two areas we should consider: the similarity between the degree from a UAS and the department's BSc degree, and a higher grade level than before. However, we must keep in mind that we have also had UAS students who have done very well in their Master's programmes.

4. Students entering the Master's programmes should take the key courses of the BSc level at the department, if we cannot determine whether they know the contents on the basis of their previous studies. This is what we are doing already. However, the department must make sure that these courses can be taken in English and with well organised instruction. We could consider some form of communal learning arrangements (study circles with an instructor, for example), where the students can have peer support while networking with each other. An individual exam could be taken to make sure students have learned the contents.

5. Master's degrees are seldom finished in the stipulated two years, but drag on past that. One key reason can be assumed to be the late start with the thesis work and that it drags on due to increasing work commitments. We must coach students in selecting their thesis topic and starting the work already in their second term at the department. Students must start their MSc thesis work at the beginning of their second year so that it can be processed by the end of their fourth term.

In order to reach this goal, the studies of the students we admit to the department must get to a good start from the beginning, without significant delay. Based on the investigation, one condition for this seems to be that each student's knowledge profile is as similar to the department's BSc degree knowledge profile as possible.

6. The marketing of the Master's programmes should be sharpened so that it makes clear to potential applicants that, in order to be successful in the Master's programme, they must have a fairly extensive and conceptual grasp of the basics in Computer Science. We must be able to communicate that we have a high expectation of knowledge, because the teaching at the department is a result of long-term development, which has constantly made the degree requirements more demanding. Good students, however, have been offered the opportunity to participate in excellent research groups if they are successful in their studies.

7. We must investigate why there is a drop in Computer Science course success index in the second term, and fix study plans as far as possible.

## **ACKNOWLEDGEMENTS**

Pirjo Moen, the department coordinator for foreign Master's students until 2011, explained to us the practices in her time. Hansi Keijonen helped us in extracting the OODI data. Jukka Paakki gave useful comments on an earlier version of this report. Marina Kurtén translated or checked the English language. In the department's strategy seminar in spring 2013 a group of students and staff members discussed the topic avidly and made many suggestions that improved this report. The strategy group included Antti Honkela, Yi-Ta Hsieh, Timo Karvi, Ksenia Konyushkova, Anna Kuosmanen, Lea Kutvonen, Pirjo Moen, Mathew Pierce, Jarkko Toivonen, Zou Yuan, Kai Zhao and Heikki Lokki (chair).

## APPENDICES

### Appendix A

#### A. SELECTING STUDENTS

##### *A.1 Marketing the Master's programmes annually*

Before the application process started in 2009, the programme information was only available in the Centre for International Mobility (CIMO) database, and there were no real marketing efforts. The information in the CIMO database is updated annually, and is distributed to other sources from it.

In autumn 2009 (students for 2010), a brochure and website were created for the sub-programmes given in English. The information was not in the university's brochure on Master's programmes, partially due to scheduling problems and partially because this was not a separate Master's programme confirmed by the Ministry of Education. The university distributed the brochure at international fairs. In addition, the brochure was sent to students who had been accepted. We did not update the brochure in later years, since the programmes were included in the university's brochure on Master's programmes.

In autumn 2010 and 2011 (students starting in 2011 and 2012), the programmes were mainly advertised through the Google AdWords campaign. The Google ad was based on key words, and is paid on the basis of clicks.

In autumn 2012, the website for the programme was reworked, but no special marketing efforts were made. The Google AdWords campaign was not used. This may be why we saw a decline in applications, both for the Computer Science and the Bioinformatics programmes. On the other hand, the application form for Computer Science was extended with several new fields to fill, so it became more of a chore to fill in the form.

##### *A.2 The annual selection process*

During the years we are discussing, the applications have been received and pre-processed by University Admission Finland (UAF). UAF is a joint academic admission service that the University of Helsinki has been using since it was established. UAF checks the authenticity and sufficiency of the degree and language diploma in the applications. Since spring 2012, UAF has screened out everyone whose language skills have not reached the level 'academic.' In previous years, the department received applications with the level 'communication,' but they were eliminated at the department because of the applicants' insufficient language skills.

UAF delivers the applications to the faculty by the end of February, and then they are sent on to the department for preliminary processing. The faculty's admissions committee meets in early April, and the applicants are notified by the end of April.

In spring 2009, the pre-processing and admission proposition was still made by the Computer Science member in the faculty's admissions committee. If necessary, this member could consult others at the department. There is no documentation of these selection procedures. The number of applicants was modest.

In spring 2010, when the number of applications grew significantly due to the programmes being given in English, the department had its own meeting for treating applications. Based on this meeting, a proposition was created for the faculty's admissions committee. Pirjo Moen did the preliminary work on the applications for this meeting.

Moen also read through all the applications and created a comparative table of them in spring 2011. The table included the degree level, university level, amount of Computer Science and Mathematics courses and their level, as well as language skills. On the basis of diplomas, she also assessed the equivalence of key courses in Computer Science.

In spring 2012, the department procedure was much the same as in previous years. This time, Timo Karvi made the detailed analysis of the applications instead of Pirjo Moen. In accordance with the model from CBU-ICT, the weaker applications were left outside the detailed analysis. Tiina Niklander screened them out on the basis of the grade average (<70%). She also made the evaluation of the university levels with the help of the academic classifications of ARWU, QStopuniversities, and webometrics. The comparative table assembled in this way was used at the department's own meeting, where an acceptance proposition was created for the faculty's admissions committee. As an experiment, a comparison number was also calculated for the summary table. However, the selections were not made solely on the basis of the comparison number, but each applicant was considered on the whole.

### *A.3 Annual admission criteria*

Annually in September, the faculty council confirms the admission criteria for the following year on the basis of the proposition from the admissions board. This is true for all the programmes at the faculty.

The admission criterion in international admissions in 2010 was 'The admissions board can use its discretion to admit students who have completed a suitable lower academic degree to an MSc programme without entrance exam on the basis of a well-argued application. It is required that applicants have the necessary language skills in Finnish, Swedish or English, and that the contents and extent of the degree they have completed is sufficiently equal to the BSc degree in the same field at the Faculty of Science.' In addition, elsewhere it is said about the selection criteria that 'Admissions are dependent on the amount of courses taken, the grade level, and the study plan.' 'Applicants can be admitted to the programmes in Physical Sciences, Geology, Chemistry, Mathematics, Computer Science, and Statistics if they have completed at least 60 credits (35 study weeks) in these subjects. If applicants have completed courses with equal contents and scope to the Bachelor of Science degree in the Faculty of Science, they can be admitted to study only for the Master's degree.'

The admission criteria for 2011 state that 'admissions are based on the quality and grade level of the degree on which the application is based, the scope and degree level of completed Computer Science or Information Technology courses, and on the application letter.'

The admission criteria in international admissions in 2012 stated that 'The admissions board can use its discretion to admit students who have completed a suitable lower academic degree to an MSc programme without entrance exam on the basis of a well-argued application. It is

required that applicants have the necessary language skills in Finnish, Swedish or English, and that the contents and extent of the degree they have completed is sufficiently equal to the BSc degree in the same field at the Faculty of Science.’ ‘The admission is based on the number, quality and grades of their course credits and on their free-form application.’

On graduates from universities of applied sciences, the separate admission regulation says, ‘The admissions board can use its discretion to accept applications from students who have graduated with good grades from an equivalent field in applied sciences and admit them to the Master’s programmes in Physical Sciences, Geology, Chemistry, Mathematics, Computer Science and Statistics. Applicants who have earned at least 60 credits (35 study weeks) from courses equal to the main subject they are applying for can be accepted. The admission is also determined by the grade level of the previous degree and the study plan.’

From the viewpoint of Computer Science, the admission criteria have been outlined so vaguely that the department can use its own evaluation of competence, but it is also easy for students to lodge a complaint for being rejected if they feel they fulfil these criteria.

The language requirements have been the same every year. We have not had any international applicants with knowledge of Finnish or Swedish, so this description only includes English. ‘The following standardized language tests along with their minimum grades or number of points are approved for proving English skills [in addition to the methods mentioned in [http://www.helsinki.fi/admissions/language\\_skills.htm](http://www.helsinki.fi/admissions/language_skills.htm)]:

- Test of English as a Foreign Language (TOEFL):  
580 points in the paper-based test (PBT) or 92 points in the internet-based test (iBT)
- Certificate of Proficiency in English (CPE): passing levels A, B or C
- Certificate in Advanced English (CAE): passing levels A, B or C
- International English Language Testing System (IELTS): grade 6.5, at least 5.5 for each part
- The test by the language services at the UH: proficiency level 5 as an average
- general language degree: proficiency level 5 as an average

In special cases, the admissions board can stretch the rules on the above-mentioned language requirements.’

#### *A.4 Students’ reasons for applying*

The students’ reasons for applying to the UH can be divided into four categories: interest in the subject they want to study, the reputation of the university or faculty (‘rank,’ Linux, the Finnish school system), the higher-level degree, and the impact of the field (especially Bioinformatics).

The students were asked where else they had applied. Out of all replies, 13 mentioned Aalto University, 6 KTH in Sweden, 5 the Tampere University (of Technology), and 4 the University of Turku. In addition, a great number of other universities were mentioned, such as other Finnish universities, as well as Chalmers, Uppsala, Tallinn, EPFL in Switzerland, TU Delft in the Netherlands, Milan, Maryland USA, Buffalo USA, Ohio State USA, and Toronto in Canada.

## B. RECEPTION OF STUDENTS

### *B.1 Before arrival*

The faculty sent all students admitted before year 2010 an acceptance letter along with instructions for what they needed to do before they arrived, but there has not been any other instruction before the students arrive.

Starting in 2010, the department coordinator (in 2010 and 2011 Pirjo Moen, in 2012 Tiina Niklander) has contacted admitted students by email in May-June.

Students who had been accepted in the international admission in 2010 were sent a welcoming email on 28 May 2010. The message reminded them of the bureaucracy involved in the arrival (registration, residence permit, housing), the housing problems in Helsinki, and directed them to the department's website for their independent orientation. In August (the 13th), a second message was sent to students who had accepted their admission place. This message focused on the practices in the initial stages.

In 2011, the contents of the welcoming letter were expanded. It included an appendix with more orientating material. The appendix detailed such things as what study skills would be needed and the students were required to make their own study plan and write a summary of one scientific article before they arrived.

In 2012, the welcoming letter was expanded even more. The assignments of the previous year were modified and their deadline brought forward, to the beginning of August. Students were asked to plan their studies in the first period, i.e. to select the courses compulsory for them and one elective course from a list. Another assignment was to read one of a given set of scientific articles and to write a two-page essay on it. One of the authors of each article was a professor of one of the English programmes at the department. The choice of articles was based on their length, fairly easy contents, and availability. Some questions to guide the writing of the essays were attached to each article. Most of the students wrote an essay.

University level international student services sent in spring and summer 2012 letters for accepted students. The university started to publish a special newsletter for international students in spring 2013. The web-pages of international student services cover important information for incoming students.

### *B.2 Orientation on arrival*

The orientation procedure for international students on their arrival in Helsinki and soon after has varied through the years. In 2006 – 2009, the responsibility for orientation lay with the faculty, and it was organised especially with exchange students in mind. Individual Master's programmes, such as Bioinformatics, were in charge of the orientation of their own students independently or in collaboration with the faculty. For exchange students, the same procedures have been in place for years and years. At first, central administration did not want to expand these procedures, claiming a lack of resources. Since 2010, the situation has been somewhat clearer, and especially during 2011

and 2012, the process has been fairly well re-considered in central administration and the faculty. However, in this process, there is not enough time (2-4 hours) for the departments and for students to plan their studies at the department.

The orientation procedure for Finnish students entering at the Master's level has still not been considered at all. All the orientation in Finnish at the department has been directed to freshmen at the Bachelor's level, and the faculty does not inform Finnish Master's students about the international Master's level orientation.

At the beginning of autumn, the first personal contact we have with students is usually in the orientating afternoon at the department, where the contact person for exchange students and the person coordinating the international Master's programmes (+ possibly some special tutors) present a class of orientation to the department, detailing studying at the department, signing up for courses, and especially with exchange students, their individual study plans. The international Master's students will later discuss their individual study plans in person with the special tutor of their own sub-programme.

### *B.3 Integration into student community*

The international students have not integrated very well into the student community due to language barriers. Most of the activities organised by the student associations are directed at freshmen in the Bachelor's stage, and is in Finnish. It is their prerogative, as voluntary organisations for students, to choose the language they want to work with. The Finnish-speaking students at the Master's level have already built their own networks and no longer participate in various student occasions.

The tutors are doing a very good job to support integration. They bring the international groups into the student association's events, but the language barrier stops international students from participating in the work of the association. The international students have mostly networked according to citizenship. The Chinese, especially, have a well working network.

Some integration happens during lecture courses, but the traditional course model of lectures and exercises does not really force students to work together, and without cooperation students may not get to know each other better.

### *B.4 How the students experience their orientation*

A free-form query was given to the students after their first week in 2010 and 2011, as a part of the department's orientation course. Based on this query, the students felt they had integrated into the student community quite well, and they gave the tutors great credit for this.

In the query done in connection with this investigation, the students' experiences of their orientation varied a great deal, but mostly on the positive side of the scale. Some improvement suggestions that were made included personal meetings, more details on integration into Finnish society, and a combined orientation for foreign and Finnish students. One hardship that was mentioned was that there was no orientation course for students starting in January.

## **C. INTRODUCING STUDENTS TO THE STUDY CULTURE OF THE DEPARTMENT**

### *C.1 Student counselling*

The counselling for students starting at the Master's level is the responsibility of the special tutor of each sub-programme, as a normal part of the process to create an individual study plan. In addition, the coordinator helps and counsels students in various matters.

The international students need a surprising amount of counselling on study techniques, time management, and other study skills. Some need to talk things through when they experience a culture shock.

Some of the counselling needs are probably due to a different learning culture at a previous institution. There are also some cultural differences between Finnish universities and universities of applied sciences.

The students are not used to making decisions on their own studies. It is typical for students from Asian learning cultures to expect to be told which courses they should attend and when. The openness of the degree requirements at the department comes as a surprise to them, and they may not be prepared to take responsibility for planning their studies at the beginning of autumn. Most of them have come to terms with this by the end of the first period.

Most of the counselling on study plans is given during the summer and the first autumn. At the end of the first spring, the students plan their second year, and they should also start to outline the topic for their Master's thesis. Unfortunately, many postpone the outline to the Christmas of their second year, and the thesis work is postponed until the third autumn.

### *C.2 Scientific writing*

Most of the international students have problems with scientific writing, and some of them with writing in English. We knew this when we were expanding the programme for autumn 2010. This is why we organised an orientation course at the department for the students to introduce them to our learning culture and support the development of their writing during their first autumn. Since one instructor was in charge of the whole group of 25 students (23 international + 2 domestic students new at the department), the students were only required to write a short – around three pages – scientific text on a topic given by the instructor. In autumn 2010, this was fairly successful and most of the students finished the assignment on time. However, some of the students did not finish it until the following spring.

In autumn 2011, the skill level of the students was weaker than the previous year. This was evident in their course performances, but was concretised in their writing difficulties. Nearly 1 in 4 of the students who started in 2011 could not finish the writing assignment, even given an extended spring deadline. They received instruction the whole time and were pressured about producing the text, but nothing came of it.

In the light of these experiences, since the faculty schedules allowed us to modify the degree requirements for autumn 2012, the orientation course was replaced with the course 'Scientific writing for MSc in Computer Science.' The course structure was modelled on the department's method of instructing the Bachelor's thesis as a separate writing course, which has been very successful. The course was attended by 35 students, some ten of which had started in 2010 and 2011. The course was completed by 31 students, so this method of instruction seems to be a good one. Of the drop-outs, over half had started in 2011. None of the students who completed the course failed it, though some of the students were not happy with their grades.

### *C.3 Complementary courses*

Before the beginning in 2009, the number of entrants to the Master's programmes, and especially the number of international entrants, was small. The department still had many exercise sessions in English at the Bachelor's level, so we could require complementary courses of the students. Especially for students with degrees from universities of applied sciences, the required course was typically Models of computation. The Networks students were also required to take the course Concurrent programming. This course was not required of the Algorithms students.

Since autumn 2009, complementary courses have not been required formally, but the students have been asked to include them in their curriculum when making their individual study plan, if they have not taken corresponding courses for their background degree.

For some students, the course names indicate that their degree should lack for nothing, but the student's skills do not support this assumption. We have observed this in programming skills, knowledge of data structures and algorithms, and the contents of the course Introduction to data communication.

### *C.4 Proficiency and courses in Finnish and English*

Students do not speak Finnish and their English proficiency varies. Some of the students with a degree from a university of applied sciences can use some Finnish, but they know the terminology of the field only in English.

The problems with language skills are not tied to how the students have proved their language skills. Most students from abroad use the results from an IELTS test to prove their proficiency in English. Applicants from Finland and other European countries have usually taken a degree programme in English in their own country, and they are not required to prove their language proficiency in any other way.

In practice, most students do very well at lectures and quite well in face-to-face discussions with their instructors. Most of the problems become evident in writing. For some, this may keep them from passing exams, when the grader cannot assess their knowledge because the writing is so poor.



## Survey for Master Programme Students of CS Department

The purpose of this survey is to find out the students' experience of the Master's programmes at the Department of Computer Science in the University of Helsinki. The survey has been sent to all students and recent graduates in the Master's programmes. In order to gain a balanced understanding of the experiences, it is very important that every student answers the questionnaire.

The survey is anonymous. The results of the survey will be used to improve the experience and services provided by the Master's programmes.

Most of the questions are in pairs asking your opinion or experience on a seven-step scale and below that a text box is available for further explanation.

### QUESTIONS

\* In which Master's programme do you study?

What was your motivation to apply to the programme?

How did you find about the programme?

\* How desirable did you view the programme at the time you applied?

Very undesirable	1	2	3	4	5	6	Very desirable	7	Not applicable
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

What other options did you consider and what other universities did you apply to?

\* How did you like our marketing information of the programme?

Poor	1	2	3	4	5	6	Excellent	7	Not applicable
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Any particular points you remember regarding the marketing information?  
Please describe both positive and negative points.

\* How was the start of your studies in the programme?

Poor	1	2	3	4	5	6	Excellent	7	Not applicable
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

How were you tutored in the beginning? What kind of guidance did you miss? Describe both useful and useless pieces of information.

\* How do you feel you have been supported in your studies?

Poorly	1	2	3	4	5	6	Excellent	7	Not applicable
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

What do you think of the different kinds of support, e.g., study counselling, language courses, scientific writing courses, integration to the community, etc.

\* How have you progressed in your studies compared to your personal expectations?

Poorly 1    2    3    4    5    6    Excellently 7    Not applicable

☐    ☒    ☐    ☐    ☐    ☐    ☐    ☐

\* How difficult (challenging) do you find your studies?      Very difficult 1    2    3    4    5    6    Very easy 7    Not applicable

☐                  ☐    ☐    ☐    ☐    ☐                  ☐                  ☐

[illegible]

\* How well do the teaching and evaluation match the learning objectives set for the courses (on average)?

Poorly 1    2    3    4    5    6    Excellently 7    Not applicable

☐    ☒    ☐    ☐    ☐    ☐    ☐    ☐

\* For how many courses have you found the learning objective matrix?

\* How much of your study material comes from your own searches? ☐ None 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ All 7 ☐ Not applicable

\* Did or do you have a job during the semester? If yes, how much have you worked or work in the job (hours per week, on average)?

	Poor	1	2	3	4	5	6	Excellent	7	Not applicable
* How do you see your possibilities in finding employment after your graduation <b>in Finland?</b>	<input type="radio"/>		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>		<input type="radio"/>
* How do you see your possibilities in finding employment after your graduation <b>internationally?</b>	<input type="radio"/>		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>		<input type="radio"/>

What future plans you have after graduation? What do you see as your career opportunities?

Poor 1 2 3 4 5 6 Excellent 7 Not applicable

\* How do you rank the programme in general?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Any further information about your experience of the programme. For example, why would you or would you not recommend the programme to your friend, or what would further improve in the programme.

#### PERSONAL INFORMATION (FOR DATA ANALYSIS PURPOSES ONLY)

\* Gender

\* Marital status

\* Years and months lived in Finland (as free text, e.g., 2y 8m) ?

#### PROCEED

Submit

© Eduix Oy



Kysely opettajien kokemuksista laitokselle FM-opintoihin tulleista maisteriohjelmien opiskelijoista ja heidän opinnoistaan.

## Kysely opettajille kansainvälisistä maisteriohjelmista

Tavoitteena on ymmärtää opiskelijoiden taustatietojen riittävyttä ja kielitaitoa. Myös selvittää kulttuuritaustoista johtuvia opiskelun ja opetuksen kannalta huomioitavia seikkoja.

Kysymyksissä haetaan sinun kokemustasi maisteriohjelman opiskelijoiden opettajana.

Tekstikenttiin voit vapaasti kirjoittaa mielipiteitäsi ja mainita konkreettisia esimerkkejä käytännön opetustilanteista.

Osaa opettajista haastatellaan erikseen tarkemmin.

Voit ilmoittaa lomakkeen lopussa mikäli olet valmis kertomaan lisätietoja haastattelussa.

Lomakkeella käytetään termiä **maisteriohjelman opiskelija** tarkoittamaan

tietojenkäsittelytieteen laitokselle tai bioinformatiikan maisteriohjelmiaan **FM opintoihin uusina tulleita opiskelijoita**, jotka ovat suorittaneet LuK-tutkinnon muualla kuin Helsingin yliopistossa.

### KYSYMYKSET

#### Mitkä maisteriohjelmat liittyvät opetukseesi?

- ☐ Algorithm and Machine Learning
- ☐ Networking and Services
- ☐ Software Systems
- ☐ CBU-ICT (Cross-Border University - Information and Communication Technology)
- ☐ Bioinformatics

	Erittäin huonosti 1	2	3	4	5	6	Erittäin hyvin 7	En osaa sanoa
* Kuinka hyvin tunnistat laitokselle FM opintoihin tulleet uudet maisteriohjelman opiskelijat LuK-opintoihin tulleista?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
* Miten hyvin maisteriohjelman opiskelijat mielestäsi pärjäävät opinnoissaan?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Millaisia kokemuksia sinulla on maisteriohjelman opiskelijoista?

(opetustilanteista, niiden ulkopuolelta).

Mainitse esimerkkejä kuvaavista opetustilanteista (positiivisia ja negatiivisia, erityisesti suhteessa LuK-vaiheen laitoksella suorittaneisiin):

	Erittäin huonot 1	2	3	4	5	6	Erittäin hyvät 7	En osaa sanoa
* Millaiset esitiedot ja -taidot maisteriohjelman opiskelijoilla mielestäsi on verrattuna LuK-vaiheen laitoksella suorittaneisiin? Erityisesti ajatellen opintojen suorittamista ja opintojakson keskeisten käsitteiden syvällistä oppimista.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Mainitse esimerkkejä havainnoistasi esitetietojen ja -taitojen osalta:

	Erittäin huono 1	2	3	4	5	6	Erittäin hyvä 7	En osaa sanoa
* Millainen <b>englannin</b> kielen taito maisteriohjelman <b>ulkomaalaisilla</b> opiskelijoilla on?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
* Millainen <b>suomen</b> kielen taito maisteriohjelman <b>ulkomaalaisilla</b> opiskelijoilla on?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
* Millainen <b>englannin</b> kielen taito maisteriohjelman <b>suomalaisilla</b> opiskelijoilla on?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Mahdollisia kommenttejasi kielitaitoon liittyen tai esimerkkejä kieleen liittyvistä käytännön opetus- tai ohjaustilanteista.

Erittäin epämotivoivana 1 2 3 4 5 6 Erittäin motivoivana 7 En osaa sanoa

\* Kuinka motivoivana koet opettamisen maisteriohjelmissä?

☐☐☐☐☐☐☐☐

Jotain muuta, mitä haluaisit tuoda esille tai kommentoida liittyen maisteriohjelmiin tai maisteriohjelmien opiskelijoihin.

En mielelläni Kyllä

\* Olen valmis kertomaan lisätietoja haastattelussa.

☐☐

Sähköpostiosoite (jos haluat ilmoittaa)

TIETOJEN LÄHETYS

Tallenna

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HELSINGIN YLIOPISTO

Tietojenkäsittelytieteen laitos

Tietojenkäsittelytieteen laitoksen julkaisuja, Julkaisusarja B Raportti B-2014-1