

THE PRACTICAL RELEVANCE OF IT EDUCATION: SKILL REQUIREMENTS AND EDUCATION EXPECTATIONS OF PRACTITIONERS

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Abstract: This paper suggests two interpretations of the practical relevance of IT education at the university level, as the congruence between the skill requirements of IT experts and the skills provided by the education, and as the congruence between practitioners' education expectations concerning the skills to be taught and the skills provided by the education. The paper analyzes these two interpretations empirically based on a questionnaire study and shows that the two interpretations differ significantly, lead to quite different conclusions about the practical relevance of the curriculum and education, and differ in their stability when background variables such as the gender, age, job category and year of graduation of the respondents are taken into consideration.

1. INTRODUCTION

The university-level education of IT experts has been of a considerable interest during the last ten years when developing curricula in the areas of Computing Engineering, Computer Science, Software Engineering, Information Systems and Information Technology (Computing Curricula 2005a), work that has resulted in curricular specifications at the undergraduate level in each of these areas.

Concurrently, there have been some attempts to investigate empirically what industry and the practitioners themselves expect from the education of future IT practitioners (Lethbridge 2000, Kitchenham et al. 2005).¹

Curriculum development in IT faces difficult challenges as to what to teach. One challenge is to decide to what extent to emphasize theoretical topics even though practitioners do not see them as important. Teaching mathematics is a good example. Both Lethbridge (2000) and Kitchenham et al. (2005) report that software engineers believe that mathematical topics are not very important for them. Does this imply that mathematics and formal methods should not be taught in SE curricula? A second major challenge in an extremely dynamic field such as IT is to what extent to emphasize immediate practical, job entry-level needs and to what extent to teach more invariant material that might support the life-long career development of future IT experts. Studies of job advertisements

¹ In general, we use the term "Information Technology" (IT) in a broader meaning than in the Computing Curricula, Information Technology Volume (2005).

tend to reflect the former (Surakka 2005), although Gallivan et al. (2004) end up in their analysis of job advertisements with an emphasis on skills for life-long learning.

Another question concerns national differences. Although the computing disciplines are inherently international, there may be significant differences between countries that justify different curricula. The five Computing Curricula reflect mainly the North American perspective, although the overview report (Computing Curricula 2005a) does recognize some international differences, among which the idea of each discipline having its own core, prevalent the US, is the most significant from the viewpoint of the content of curricula. More from the practitioner perspective, one should note that countries differ in their industrial structure and in the range of IT specialists that they need.

The purpose of the present paper is to analyze the practical relevance of IT education both theoretically and empirically. The paper suggests two major interpretations of this practical relevance, as the congruence between the skill requirements of IT experts and the skills provided by the education, and as the congruence between practitioners' education expectations concerning the skills to be taught and the skills provided by the education.

The empirical comparison of the two interpretations of the practical relevance of IT education in this paper comes from one country, Finland, which is fairly advanced in applying IT in various spheres of life and which also has a fairly strong IT industry, especially in the telecommunications sector.

2. PRACTICAL RELEVANCE OF IT EDUCATION

The practical relevance of IT education is a significant concern, since IT experts are educated to work competently in different IT occupations in practice. One can identify two major interpretations of this practical relevance in current empirical evaluations of the education of IT experts. The first anchors it to the skills required in practice. Focusing on Information Systems, Leitheiser (1992) analyzed IS managers' perceptions of the importance of 54 skills for systems developers and 26 skills for technical specialists, while Trauth et al. (1993) compared an IS faculty's perceptions of the importance of a number of items describing the tasks IS practitioners perform, their technical skill requirements and interpersonal and business skills with those of the IS practitioners themselves. Lee et al. (1995) conducted quite a similar study of the critical skills for IS practitioners, but excluding IS faculty respondents. Tye et al. (1995) targeted their questionnaire study at all computing degree students who had graduated from one department in Hong Kong in 1988 to 1993, asking them to evaluate the importance of the 54 IS skills identified by Leitheiser (1992) and the extent to which

these skills were emphasized in the curriculum. Among other things, the analysis included a comparison between the importance of the skills and the emphasis placed on them in the curriculum.

The second approach anchors the practical relevance to the respondent's career development. The central theme of the surveys conducted by Lethbridge (1998, 2000) was to ask respondents to evaluate how useful the material they learned at university or college has been for their career as software developer or software managers. Kitchenham et al. (2005) essentially replicated Lethbridge's survey in the UK, although they expanded the number of topics from 57 in Lethbridge (1998) and 75 in Lethbridge (2000) to 78. The idea of Lethbridge (1998, 2000) was obviously to capture the relevance of the education for the respondents' actual careers in the field. If their careers since graduating have not yet been very long (4-7 years in Kitchenham et al. 2005), the respondents may be able to evaluate the usefulness of the material they learned over their career up to that time. One should note, however, that the question does not concern what the students were taught but what they learnt, so that the answers are extremely subjective – their subjective perceptions of the value of their personal learning experience for their personal career.

One central problem in curriculum design is that a curriculum cannot cover all potentially relevant material. Curriculum designers must choose how to emphasize different bodies of material, and in the case of electives and optional studies the students must decide what material to choose. The studies of practical skill requirements reviewed above do not include this problem of choice and weighting. It may well be that the practitioners themselves accept that IT departments cannot teach them all the skills they need in practice but must concentrate on some core topics.

Recognizing this, we suggest a third interpretation of the practical relevance of IT education, as the congruence between practitioners' expectations concerning the skills to be taught and the skills provided by the education.

The present paper will focus on two interpretations of the practical relevance of IT education, one anchored in the skills required in practice and the other in expectations regarding the education. The paper has two purposes:

1. To analyze empirically how the two interpretations differ.
2. To analyze the stability of the two interpretations.

As reviewed above, there is some empirical research that addresses the first interpretation, although it is from the early 1990's and therefore not necessarily valid any longer. To our knowledge, the

second interpretation is a totally new idea, and consequently there is no prior research that addresses it.

3. RESEARCH METHOD

To answer the above questions, we conducted a questionnaire study targeted at graduates of the Department of Information Processing Science, University of Oulu. Established in 1969, the department has a M.Sc. program in IT with a number of possibilities to specialize.² The first students graduated at the M.Sc. level in 1973, and the number of graduates by the end of June 2006 was 749. The questionnaires were sent to 680 of these.³

The questionnaire consisted of three major categories of items:

1. The importance of skills in 130 topics from the viewpoint of the respondent's current job, ranging from "no skill requirements" (0) to "very high skill requirements" (5).
2. The skills provided in the curriculum of the Department of Information Processing Science in each of the 130 topics, ranging from "no skills provided" (0) to "very high skills provided" (5).
3. Respondents' views of the percentage of the teaching that should be allocated to each of the 130 topics.

The last question was to be answered hierarchically. First, the respondents were asked to allocate teaching between 10 topics within each of 13 knowledge areas to be introduced below, reaching a total of 100%. They were then asked to allocate teaching between the six technical knowledge areas and separately between the seven non-technical knowledge areas, in each case to a total of 100%, and finally, they were to allocate teaching between the technical and non-technical areas to a total of 100%. The weight given to each of the 130 topics was then calculated as a product of these three percentages.

The identification of the 130 topics started out from the classification of the Body of Knowledge (BoK) for IS experts into technical knowledge, application knowledge, application domain knowledge, organizational knowledge and system development knowledge as proposed by Iivari et al. (2004) but expanded to include "communication and co-operation skills" and a category "miscellaneous".

Technical knowledge as defined in Iivari et al. (2004) was then further divided into six areas: 1) Hard-

² The department's M.Sc. curriculum can best be characterized as a 4-year programme of full-time studies, although there have been nation-wide changes in M.Sc. programmes in Finland over the years. At the beginning, the main focus of the curriculum was on Information Systems, but it was expanded in the 1980's to include Software Engineering and during the last ten years to comprise digital media, mobile computing and software business.

³ Of the 749 graduates, 54 had refused to give their addresses, 5 had died and 10 participated in the pilot questionnaire and were therefore excluded.

ware, operating systems and telecommunications; 2) Programming and program languages, 3) Implementation technologies, 4) Databases and data modelling, 5) User interfaces and usability, 6) Computer security. Correspondingly, systems development knowledge was decomposed into two areas: Systems development approaches and Systems development process models. This gave the total of 13 knowledge areas. The detailed list of the 130 skills was based on previous research (especially Lethbridge 2000) and the Computing Curricula reports (Computing Curricula 2001, 2002, 2005b, Software Engineering, 2004).

To answer all the three categories of questions would have led to a long questionnaire, which would probably have had an effect on the response rate. To shorten the questionnaires, we developed three versions, each including two categories of questions, targeted as follows:

1. Version 1, focusing on the importance of the 130 skill requirements (category 1 questions) and the respondents' views regarding the percentage of teaching that should be allocated to these (category 3 questions), was targeted at the 320 graduates from 1973-1994.
2. Version 2, focusing on the importance of the 130 skill requirements (category 1 questions) and the skills provided by the curriculum of the Department of Information Processing Science (category 2 questions), was targeted at a randomly selected half of the graduates from 1995-2006, i.e. 180 graduates.
3. Version 3, focusing on the respondents' views regarding the percentage of teaching that should be allocated to the 130 skills (category 3 questions) and the skills provided by the curriculum of the Department of Information Processing Science (category 2 questions), was targeted at the other half of the graduates from 1995-2006, i.e. 180 graduates.⁴

The questionnaires were mailed to the respondents in May-June, 2007, with a request to return them in the enclosed prepaid envelopes. Eight of the 680 questionnaires were returned unopened because of a mistaken address. Altogether 210 replies were received, 90 from **respondent group 1** (response rate 28.1%), 87 from **group 2** (response rate 48.3%) and only 33 from **group 3** (response rate 18.3%). Sixteen of the replies were so incomplete that we were forced to reject them, leading to 194 completed questionnaires. A likely reason for the lower response rates in groups 1 and 3 is that their questionnaires included the weighting questions, which were more complicated to answer. Because of practical problems in mailing, we cannot safely use the return date to evaluate the non-response bias.

⁴ The reason for the above grouping was that we did not see any point in presenting category 2 questions to the oldest graduates. We also anticipated that the response rate among the oldest graduates would be lower. This was why we targeted the first version at a higher number of graduates than the other two.

Table 1: Profiles of the respondents

Gender		Age		Specialization		Job category	
Male	13	25-	3	Digital media	30	Teacher &	2
Female	5	29	0	Information systems	100	researcher	8
Missing		30-	5	Mobile services	7	Analyzer &	
		39	1	Software business	5	designer	6
		40-	3	Software engineering	49	Lower management	2
		49	9	Missing	3	Higher management	5
		50-	6			Other	1
		59	1			Missing	2
		60-	6				6
		Missing	7				1
							4
							1
							3

The profiles of the respondents are described in Table 1. There were 28 respondents with the job category “Teachers and researchers”. We tested whether this category differed from the rest, but as we did not find any significant differences in either skill requirements or education expectations in any of the 13 knowledge areas we decided not to exclude them from the data set.

4. RESULTS

The results of respondent group 1, contrasting skill requirements and education expectations at the level of the 13 knowledge areas, are described in Table 2. The detailed 130 skills requirements of each respondent were converted into weighted requirements using the formula $\text{weighted importance} = \text{importance} * 100/m$, where m is the sum of the importance scores attached to the 130 skills by the respondent. The weighted importance of the skills and the weights of the education expectations in each of the 13 knowledge area are calculated as the sum of the corresponding values for the ten detailed knowledge units.

Table 2: Weighted skill requirements vs. education expectations (n = 90)

Knowledge area	Weighted skill requirements	Education expectations
Hardware, operating systems, telecomm's	7.00	6.12*
Programming and programming languages	6.48	7.79*
Implementation technologies	4.88	5.33
Databases and data modelling	7.51	8.65*
User interfaces and usability	6.26	8.50*

Computer security	7.42	6.93
Systems development approaches	7.33	10.60**
Systems development process models	9.97	10.25
Application knowledge	6.82	6.28
Application domain knowledge	5.17	5.97
Organizational and business knowledge	10.32	9.42
Communications and co-operation skills	14.59	11.73**
Miscellaneous	6.04	4.54*

* $p \leq 0.05$ ** $p \leq 0.01$ *** $p \leq 0.001$

As seen in Table 2, there are significant differences between the weighted skill requirements and education expectations when tested using the paired-samples t test. Education expectations concerning “Hardware, operating systems and telecommunications” are significantly lower than the weighted skill requirements, one explanation for which may be that much of this knowledge is changing so fast that practitioners do not see any reason for investing too much education effort in it. In the case of “Programming and programming languages”, “Databases and data modelling” and “User interfaces and usability” the situation is just the opposite, i.e. it may be that the practitioners regard these as core areas that must be taught in any case. The respondents’ expectations concerning “Systems development approaches” are clearly higher than the weighted skill requirements, while the reverse is true of “Communication and co-operation skills”, where the (weighted) requirements are clearly higher than education expectations, and of “Miscellaneous” skills.

In the case of respondent group 2 ($n = 81$) we contrasted the skill requirements with the skills provided by calculating the gap between the two. The paired-samples t-test identified seven significant negative gaps where the Department of Information Processing Science had failed to satisfy the practitioners’ skill requirements and only two significant positive gaps where the skills provided had exceeded those required.

We also contrasted education expectations with the skills provided by the curriculum, by converting the skills provided as indicated by each respondent (measured on the scale 0-5) to weighted skills provided using the formula: weighted skills provided = skills provided * $100/m$, where m is the sum of scores on skills provided given by the respondent. Because of the low number of valid responses obtained from group 3 ($n = 24$) we decided to test the gap by contrasting the education expectations expressed by groups 1 and 3 combined ($n = 114$) with the skills provided as reported by groups 2 and 3 combined ($n = 105$) and assessing its significance using the independent samples t-test.⁵ The

⁵ Note that in the second case the samples are not independent, since respondent group 3 ($n = 24$) belongs to both.

essential finding in the comparison between the gaps (skills provided – skills required vs. skills provided – education expectations) was that the latter gap gives quite a different picture from the former gap, as there were three significant negative gaps and four significant positive ones between education expectations and skills provided.

The influence of background variables on the skills requirements is examined separately for each knowledge area in Table 3. The results are based on regression analyses of respondent groups 1 and 2 combined ($n = 171$). Note that the job categories “Teachers & researchers” and “Others” were deleted from these analyses so that the variable described the organizational level of the respondent.

Table 3. Relationships between background variables and skill requirements

Knowledge area	Gender	Age	Graduation year	Job category	R2
Hardware, operating systems, telecommunications				0.25*	0.11
Programming and programming languages	0.40***			-0.33*	0.19
Implementation technologies		0.38*			0.15
Databases and data modelling		0.45**			0.17
User interfaces and usability					0.03
Computer security		0.38**		0.43***	0.32
Systems development approaches	0.21*	0.38*			0.22
Systems development process models					0.08
Application knowledge		0.43**		0.26*	0.24
Application domain knowledge		0.52***		0.32**	0.41
Organizational and business knowledge				0.53***	0.32
Communication and co-operation skills	-0.28*			0.45***	0.19
Miscellaneous		0.51**	0.32*	0.24*	0.25

* $p \leq 0.05$ ** $p \leq 0.01$ *** $p \leq 0.001$

As seen in Table 3, the skill requirements are highly dependent on the background variables. Male respondents reported higher skill requirements in programming and programming languages and in systems development approaches than their female colleagues did, while female respondents reported higher communication and co-operation skill requirements. Age influenced skill requirements in seven knowledge areas – in the sense that *ceteris paribus* skill requirements tend to rise with age, but skills were significantly related to the year of graduation only in one knowledge area. Skill requirements were also closely related to job category. While skill requirements in programming and programming languages tend to decrease as one proceeds in one’s career, those in application domain knowledge, organizational and business knowledge and communication & co-

operation in particular tend to rise. Similarly skills in security issues tend to rise with age and job category.

When we performed a similar regression analysis to examine the relationships between background variables and education expectations in respondent groups 1 and 3 combined ($n = 114$) we found only one significant regression coefficient, between job category and application knowledge ($\beta = -0.24, p \leq 0.05$). Comparison of the results regarding education expectations with those in Table 3 clearly shows that skill requirements are highly dependent on the respondents' background variables while education expectations are virtually independent of these. This suggests that the education expectations expressed by seasoned practitioners are much more stable than their skill requirements.

5. DISCUSSION AND CONCLUSIONS

The above analysis compared two interpretations of the practical relevance of IT education, showing that these differ significantly, lead to quite different conclusions regarding the practical relevance of the case curriculum, and differ in their stability when different background variables are taken into consideration.

One explanation for the finding that, even though skill requirements differ depending on the background variables, education expectations remain very much same might be that the education that the respondents have received has indoctrinated them into expecting certain topics. One should note, however, that the respondents (in groups 1 and 3) who expressed their education expectations had graduated between 1973 and 2006, so that it is unlikely that the education provided could alone explain this consistency of expectations.

The above results have clear practical implications for curriculum design. We conceive of it as a two-stage process:

1. The design of the obligatory studies, informed by the education expectations expressed by practitioners.
2. The design of elective and optional studies, informed by the skill requirements of practitioners.

The phrase "informed by" above points out that we do not see that the curriculum design should be entirely based on the education expectations and skill requirements of practitioners, as the curriculum may also reflect the structure, themes and research topics of the respective discipline. Nevertheless, it is important to note that the fact that the respondents' education expectations

were independent of the background variables implies a certain consensus among practitioners about what should be taught in university IT curricula. It seems natural to design the core of the curriculum – especially the obligatory studies – so that they reflect these consensual education expectations.

As emphasized several times, we cannot expect IT curricula to provide all the skills required in practice.

Yet, we regard the skill requirements of practitioners as informative when designing elective and optional studies, which can complement the core of the curriculum so that they focus on knowledge areas and topics where the weighted skill requirements are clearly higher than either the education expectations or the skills actually provided.

The present paper has its limitations. Its empirical results are based on responses received from graduates of one department in one country. The findings concerning the skills provided in particular inevitably reflect the curriculum in force and education provided from 1990 onwards, since the majority of the respondents had graduated from the department between 1995 and 2006. It is beyond the scope of the present paper to describe the department's curriculum or its various versions in detail.

One of the starting points for the present paper was that each country may have its specific features - such as its industrial structure and the variety of IT specialists needed – which justify different points of emphasis in the education of IT experts. This paper reports results from one country that is fairly advanced in the development and application of IT, but it would be interesting to see comparable data and analyses from different countries. We therefore hope that the present paper will stimulate similar studies in other countries.

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