Learning Style Models and Teaching of Computer Science

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Abstract

This paper discusses learning style theories with a focus on the VARK model and Honey-Mumford questionnaires. The traditional views are described and a restatement in terms of abilities or skills is proposed. Then the learning style methodology is applied to teaching computer science. A hypothesis is made that most of computer science students share kinaesthetic/activist preference and teaching of computer science is dominated by the kinaesthetic culture.

Contents

1 Learning Styles and Their Classifications

The most general definition of a *learning style* is "an individual's preferred way of learning" ([HM92]); in other terms it is a collection of preferences for the ways a learner receives information[1] (see [Fle95]).

What preferences should be taken into account? We may take an extensive approach and consider *all* preferences. A semi-humorous example given by many books on learning is the temperature in the lecture room; if we adopt the all-inclusive approach, it should also be considered. In the limit, therefore, there are as many different learning styles as there are human beings.

One cannot but agree that this all-inclusive approach is of limited theoretical or practical use. The times of home education and personal teachers have passed. Although individual tuition is still present in the modern education system (consider, e.g., relations between a project student and a supervisor) and is of particular importance at higher levels (e.g., for postgraduate students or for all students at universities like Oxford and Cambridge), education nowadays is more industrialised. A great deal of teaching is done in groups including very large groups up to hundreds of students.

Therefore we need models. Individual styles should be grouped together and classified according to some schemes. What scheme shall we adopt? Book [Fle01] gives (after [Dav93]) the following classification of classifications, i.e., a system of categories into which learning style models fall. A learning style model may concentrate on

1. personal characteristics (e.g., extrovert vs introvert),

2. information processing (e.g., holistic vs sequential approach),

[1] This restatement suggests that "learning" is the same as "receiving information"; here I am not going to elaborate on the subtle difference between the two concepts.

3. social interaction (e.g., learning oriented vs grade oriented),

4. instructional preference (the medium in which learning occurs best).

This classification (of highly questionable validity) suggests that models of learning are abundant.

A model should be convenient, easy to remember and apply, and thus necessarily concise. As [HM92] points out, any categorisation is a convenient oversimplification. This should be kept in mind all the time. An individual case may defy any categorisation. An individual learning profile may contain features that are not covered by any categorisation but are still crucial to the performance of a particular student. In extreme cases factors not covered by classification schemes may gain vital importance even for big groups. For example, once, after multiple complains from students a lecture of mine was moved to a different lecture room because the normal one was too cold. I personally did not notice it: when lecturing I have a habit of running left and right in front of the blackboard and this habit kept me sufficiently warm. Thus the lighthearted temperature factor may override any factor of nobler theoretical foundation.

Having said that, I shall go back to considering learning style models and classifications. In Sect. 2 I shall describe and discuss two learning style classifications. Finally, in 2.5 I shall suggest a way of reformulating learning style theories that seems more appropriate to me. Then in Sect. 3 I shall discuss applications of learning style theories to computer science, which is the discipline I work in.

2 Learning Style Theories

I shall start by discussing the VARK model in Subsect. 2.1 and its implications for teachers and learners in Subsect. 2.2. Then I shall consider a similar alternative classification in Subsect. 2.3. Then in Subsect. 2.4 I shall discuss validity of these theories with examples from my experience. Finally I shall suggest a slight restatement of VARK in Subsect. 2.5.

2.1 VARK Model

The VARK model has been developed by Neil Flemming of Lincoln University (Canterbury, New Zealand) and his colleagues. In this paper I am relying on

the description of this theory as given by its creators in [Fle01, Fle95, FM92].

According to [Fle01], the VARK model falls under item 4 of the classification given above, i.e., it refers to the medium in which students prefer to receive information. The VARK model identifies four different media and, respectively, four distinct learning styles. These styles are visual, aural, reading/writing, and kinaesthetic. The name of the theory is the acronym of these four terms. Let us consider them briefly one by one.

Speech is the most common mode of information exchange in human society. Anthropologists claim the development of speech to be one of the crucial stages in the evolution of ancestors of homo sapience. We receive a lot of information by ear. For people with *aural* preference it is the preferred and most efficient way of receiving information. Students with this preference learn best from lectures, discussions etc.

The development of writing and subsequently the invention of a printing press were no doubt crucial stages in the development of the human civilisation. People from the *reading/writing* group prefer to receive information from written or printed words. Students with this preference learn best from textbooks, lecture notes, handouts, etc.

Members of the third group, *visuals*, like information to arrive in the form of graphs, charts, various diagrams etc. They are particularly sensitive to matters like colour coding or spatial layout.

The last group, *kinaesthetics*, need concrete, multi-sensory experience. They learn by doing. Students with this preference learn best from practical sessions, field trips, experiments, role playing or simulation, etc. In order to acquire conceptual and abstract material they need it to be accompanied by analogies, metaphors, and real life examples.

An immediate addition to this four groups classification are the groups of various multi-mode preferences. People with multi-mode preferences, "lucky ones" ([Fle95]), can get information using several ways equally well. The ideal situation is, of course, complete multi-modality; people possessing it can use all four media.

The classification is rather intuitive and self-explanatory. Note, however, the difference between readers and visuals. Although both of them prefer to use their eyes to get information, the form of that information differs. In the case of visuals it is graphs and diagrams while in the case of readers it is printed words. The difference may be compared to that between text-based

computer systems and computer systems having graphical user interfaces[2]. It is explained in [FM92] and [Fle01] that the creators of VARK originally borrowed Stirling's model from [Sti87] with three categories, visual, aural, and kinaesthetic, but later came to the conclusion that the visual preference should be split in two. One of the motivations was the speciality of Neil Flemming himself: being a geographer, he observed that some people have particular difficulty reading maps, i.e., acquiring essentially visual information (see [Fle01]).

The difference among these groups is not confined to the classroom. People with different preferences are likely to respond differently to a range of real-life situations. For example, when experiencing a difficulty operating a computer program or a complicated piece of equipment an aural is likely to phone a help line, a reader will concentrate on the instruction manual, while a kinaesthetic will attempt to fix it by trial and error.

How can we detect the preferences of a particular person? A most natural approach is to use questionnaires. Neil Flemming and his colleagues developed a range of questionnaires that could serve as a "diagnostic tool" and also encourage the students to think on their learning styles (I shall concentrate on this feature later). A typical question suggests a real-life situation and offers a choice of possible responses. Here is an example taken from [FM92]:

Q: You are not sure whether a word should be spelled 'dependent' or 'dipendent'. Do you:

- look it up in the dictionary,
- see the word in you mind and choose the best way it looks,
- sound it out in your mind,
- write both versions down.

The answers hint, respectively, at a reading, visual, aural, and kinaesthetic preference. The person taking a questionnaire scores points corresponding to each preference and the points reveal their VARK profile. The use of questionnaires leads to some conceptual difficulties (see a discussion

[2]Early and primitive computers could only communicate with the user through the command line. For example, DOS operating system is command-line oriented. Modern systems, e.g., Microsoft Windows, rely on fancy interfaces, icons, use of the mouse, etc.

in Subsect. 2.4); note, however, that a questionnaire produces a soft profile rather than a hard and restrictive classification.

In [Fle01] one may find results of a big survey carried out over the Internet. These results suggest that following distribution of preferences among the people who took it:

- VARK (completely multi-modal): 30%,
- visual 3.6%,
- aural 5.2%,
- reading/writing 17.1%,
- kinaesthetic 17.0%.

The rest is covered by various multi-modal combinations. Thus, the author suggests, in a classroom of 30 students there will be 17 multi-modal, 1 visual, 2 aurals, 5 readers, and 5 kinaesthetics. I shall discuss the validity and generality of these results later, but at least they give some hint at the proportions.

2.2 Implications of VARK for Teachers and Students

Practical implications are the ultimate way for judging the validity and usefulness of a theory. What are the practical consequences of the VARK model? I am now moving on to the fundamental concept of a matching.

In [Fle01] Neil Flemming describes the history of VARK and reveals one of the observations that draw him to the creation of the theory. Being a school inspector in New Zealand, he was struck by the fact that some students learned well in apparently poor learning environments while some achieved little in much better surroundings. Of course there is nothing essentially new in this observation; everyone involved with education noticed that quality of teaching and students' success do not necessarily correspond. Neil Flemming has managed, however, to provide an explanation in terms of learning styles.

The principle of matching can be formulated as follows. Learning occurs best if the learning style of the student corresponds to the presentation style of the teacher. If there is a mismatch, the student will be hindered in their learning despite the best intentions and best efforts of the teacher.

Obviously the idea of matching can be applied to a range of different learning models. It is claimed in [Fle01] that "the concept of matching is the most important contribution of VARK to effective strategies for teaching and learning".

So what shall we, teachers and students, do? How can we combat mismatch and achieve perfect matching? One may think of the two approaches, teacher-centred and student-centred.

The teacher-centred approach suggests that it is the teacher who should be responsible for achieving the matching. As [Fle01] puts it, in an ideal world the teacher will hand out a VARK questionnaire on the first day, find out about the preferences of the group, and tailor the course to the group needs. In the absence of any evidence concerning the students preferences, the teacher should assume that their students represent a wide range of learning preferences and should try and care for as many as possible.

One may argue that the traditional academic environment is biased towards reading/writing preferences. Textbooks, study materials, and even exam papers are usually in print. The students who favour reading succeed in such a system and become teachers themselves. The system thus reproduces itself. As [Fle95] puts it, many university teachers "are clones of the read-write teachers who taught them".

It is suggested in [Fle95] that university teachers have a lot to learn from creators of advertising materials. It is essential for copywriters to target as wide a section of the market as possible. Excluding a substantial group of customers may mean immediate financial failure for them. Arguably, the advertising industry has long used the principles of VARK (without explicitly formulating them) addressing visuals with attractive coloured layouts, kinaesthetics by quotes from satisfied consumers etc[3].

The student-centred approach suggests that it is the student who should bear the burden of establishing the matching. This approach is promoted most vigorously by [FM92]. As [FM92] (rather pessimistically) claims, "it is simply not realistic to expect teachers to provide programs that accommodate the learning style diversity present in their classes, even if they can establish the nature and extent of that diversity". Another argument in favour of the student-centred approach is the recognition of the fact that universities are supposed to prepare students to real-life situations and in non-academic life

[3]I most sincerely hope that in following this sensible piece of advice academics will not overdo and the academic materials will not become as disgusting as TV commercials.

one cannot expect "the teacher" to care for all "learning preferences".

So what can a student do? There are two options for them, according to [Fle95], either "to develop new modes" or to "enhance present preferences". It is questionable whether the former is possible at all because it is not clear whether learning styles can change with time (I shall concentrate on this problem in Subsect. 2.5). Let us therefore concentrate on the latter.

The creators of VARK have carried out a wide campaign to promote what they call the "meta-cognitive awareness" among the students of Lincoln University. Students were encouraged to think about their learning preferences and of possible ways of utilising them to make learning more efficient. According to the anecdotal evidence given in [Fle95] and [FM92] the campaign met an immense success.

Here are some examples, as given in [Fle95] and [FM92]. A student exhibited a strong preference for aural information. He liked listening at lectures and understood a lot but took poor notes. This, quite naturally, presented a difficulty in revision. A brilliant solution for this student was reading his revision notes onto a cassette tape and listening to his own summaries.

Another example is a student with strong visual preferences. After becoming aware of them he started to rely on visual strategies. His lecture notes started looking "like an artwork folder". As a result he achieved A instead of usual C in the subject where he used such techniques.

The changes do not have to be so dramatic. A student said, "I rearranged my study notes for the four subjects in four different colours. That way I can easily filter out the stuff I need when I am doing an exam for Economics because it is all in green". This is how the awareness of a visual preference can be of substantial help.

In [Fle95] the outcomes are summed up as follows. "At Lincoln University we have students voluntary saying 'thank you' for the benefits they have gained from discussing the question 'How Do I Learn Best?' "

2.3 Other Learning Style Models: LSQ

As I mentioned earlier, there exists a vast number of learning style models and categorisations. I shall pick one, namely, that by Honey and Mumford and consider it as an alternative to VARK. The classification by Honey and Mumford is highly popular: [FKM03] recommends it as "the best known categorization of learning style". In my description I shall rely on [HM95] and [HM92].

This model concentrates particularly on learning style questionnaires. As compared to VARK questionnaires, those by Honey and Mumford are much more elaborate; the problem of designing the questionnaires and interpreting the test results has received much more attention than in the case of VARK. The authors have accumulated a significant amount of statistical data and even suggest that questionnaire results should be interpreted differently for people from different occupational groups (e.g., activist scores from the range 12 to 14 manifest a very strong activist preference for a production manager, but only a moderate activist preference for a salesperson). In recognition of this fact and also following the authors' own usage, I shall refer to this model as LSQ, which is the acronym for Learning Style Questionnaires.

LSQ identifies four distinct learning styles. *Activists* enjoy new and immediate experiences and their learning is dominated by experience. They tackle problems by brainstorming and often act without proper consideration of consequences. To sum up, they can be said "to thrive on the challenge of new experiences". By contrast, *reflectors* are cautious and thoughtful. Before coming to a conclusion they gather and analyse data from different sources. To sum up, they like "to stand back to ponder experiences". *Theorists* exhibit a consistently logical approach. They integrate observations into logically sound theories and value rationality. To sum up, they like "to analyse and synthesise". *Pragmatists* like trying new ideas and checking whether they work in practice. They are "essentially practical" and like "making practical decisions and solving problems".

The four LSQ styles correspond to the four stages of the "Kolb learning cycle". The "Kolb learning cycle" model of learning, introduced in [Kol84], suggests that successful learning should pass through the following stages: *Concrete Experience* (having an experience), *Reflective Observation* (reviewing the experience), *Abstract Conceptualisation* (concluding from the experience), and *Active Experimentation* (planning the next steps).

As far as the practical implications of LSQ are concerned, its creators discuss both what I referred to as a "student-centred approach" and a "teacher-centred approach" above. In [HM92] they suggest that trainers should take the questionnaires to identify their learning style and reflect on the influence this style exercises over their teaching. However the "student-centred approach" gets much more of their attention. In fact the whole LSQ model is targeted at a wider, not necessarily academic, context (which should partially be attributed to the management consultancy background of its creators as opposed to the academic background of Neil Flemming). As I mentioned

above, in the non-academic context there is not really a "teacher" who can be entrusted with a task of catering for students' preferences.

The creators of LSQ are positive that learning styles can change "either at will or by change of circumstances". That is why [HM95] provides a range of advice on both "making best use of your learning strengths" and improving weak aspects of learning style. By strengthening underdeveloped styles a person may become "a more rounded learner". Moreover, such development does not have to be a result of deliberate conscious activity. A person thrown into a situation encouraging a different learning preference (e.g., by changing a job) will probably retain their "first love" preference but also enhance their overall learning "repertoire".

2.4 Discussion

This section contains a discussion of VARK and learning styles classifications in general.

As I mentioned above, the creator of VARK believes the idea of matching to be his principal contribution towards the theory of learning styles. I agree that this idea is of fundamental importance. The following example going back to the times when I was a mathematics student at Moscow State University (MSU) supports my strong conviction.

This incident occurred at one of the so called special courses. Special courses are a unique feature of MSU. They are not a part of the standard curriculum; they usually run in the late afternoon or evening after regular classes are over. They usually cover highly specialised areas and are given by researchers working in those areas. The chief intention for lecturers is to find students for projects and future postgraduates to supervise; the chief intention for students is to get to the forefront of research in a particular area. A typical special course is attended by only a handful of students (and it is not totally unusual for a special course to disperse completely due to the lack of popularity) but those attending are highly motivated learners. They come because they are interested rather than because they have to. The lecturers are highly motivated too: they teach things they specialise in to students who want to learn them[4].

[4]Special courses are not really compulsory for either students or lecturers. The students have to take a certain number of these courses over several years and lecturers get some recognition in terms of teaching allocation, but as a rule both do more than required.

The particular course to which I would like to refer had great influence over my research interests[5]. The lecturer giving it is a world-famous researcher (and, besides, a rather well-known educationalist in Moscow). The student I would like to describe later obtained a PhD from one of the top universities in the United States. In the class he was always sitting at the front desk and taking very careful notes. To sum up, both were talented and highly motivated.

The lecturer was convinced that the best way of communicating knowledge was a discussion. He encouraged students to participate, to ask questions, to voice guesses and opinions, etc. The student in question, however, always obstructed the interaction by taking notes and requesting time to write things down. This provoked heated discussions:
"Why are you writing everything down? You should try and understand things instead!"
"If I have my notes, I can sit down afterwards and take in the material."
"But why do you need to take in the material afterwards? Ask your questions now! Here I am available to answer them. I shall only be happy to explain everything to you and the others!"

The lecturer and the student behaved like classical examples of stubborn and slightly comic mathematicians; their argument dragged on for weeks and provided invaluable entertainment and distraction to other participants.

Using the VARK theory I can immediately explain the situation in terms of a mismatch. The lecturer and the students adhered to aural and reading preferences, respectively. In terms of VARK it is just that simple.

As far as I am concerned, I could understand the student in question very well. I also relied heavily on written and printed words for my studies. I could not but agree with an old saying that in lectures information goes "from the notes of the lecturer into the notes of the student, passing through the minds of neither" [Bea03]. I usually learned little from lectures and regularly nodded off. The real learning occurred when I took my notes (or in the worst case photocopies of someone else's note) and a big pile of books and went through the material. This strategy served me well[6] but if I had been aware of VARK theory I would have organised my studies in a more efficient way.

[5]I recognise this influence in the acknowledgement section of my PhD dissertation.

[6]I achieved a degree with a distinction having only one mark below "excellent" on my final transcript.

Thus I am convinced that there is at least some truth behind VARK. However some other aspects of this theory are, in my opinion, more open to question. The data from an Internet survey given above suggest that more than 50% of all participants fell into the grey area of various mixed preferences. This raises serious doubts concerning the reliability and usefulness of the theory: you just cannot put more than one half of your examples into the "unclassified" heap!

In fact the problem of detecting learning preferences leads to serious difficulties even within the VARK framework. A questionnaire is a printed matter. Will not it be more appealing to readers? This is acknowledged in [Fle95]: ideally there should be several versions of the questionnaire, e.g., an aural one. The same considerations apply to the question of the validity of the Internet survey results: the results are skewed towards preferences of Internet users (see [Fle01]). As we shall see in Sect. 3, one may argue that the share of kinaesthetics among them should be higher. This effect should have been particularly strong at the time when the survey was taken: in the beginning of 90s Internet was not so widespread and popular as it is now.

The number and the nature of categories are not entirely convincing. However there is one important argument in favour of VARK classification, namely, its pragmatic nature. The classification does not have the form of the Cartesian product of a number of binary oppositions. The author added further categories as he observed them in the real life. The resulting construction is not theoretically elegant but it is highly viable and open to possible extensions.

By contrast, the structure of the LSQ classification raises more questions. LSQ looks more like a complete theory, its classes corresponding to stages of the Kolb's cycle. The creators mention this as one of the key advantages (see both [HM92] and [HM92]). It is not clear, however, why such correspondence should occur at all. The stages of learning and the learning styles are two different things; so to say, one of them spreads out in time while another one in space. The correspondence looks artificial and scholastic to me.

Another unsolved question is the problem of where the VARK preferences actually sit. What determines them and can they be changed? Flemming is keen on linking VARK to either NLP[7] or left/right-brain theories that explain

[7]VARK is certainly close to NLP *stylistically*, provided NLP is thought of as a set of techniques, a collection of practical recipes for solving various psychological problems. Its pragmatic approach is similar to that of NLP.

human behaviour through the aspects of the architecture of the brain. The classification would then be determined by neuro-physiological processes.

Since the middle of 90s NLP has rather gone out of fashion; nowadays NLP is often treated as pseudoscience and an NLP explanation does not sound as convincing as it used to. I would raise another objection however. A fundamental problem with the VARK classification is that some of its classes clearly have physiological background while some are cultural. Eyes are organs of the body and the visual medium is thus used by nearly all higher animals. The speech lays on the border between biological and social worlds. The difference between visual and reading preferences is entirely cultural. For example, the peoples of Far East use hieroglyphic writing and to them these two preference should mean an essentially different thing than to us (this problem is touched in [Fle01] but is not explored in much detail). It is therefore unclear how preferences so different in their nature may be linked into a single framework.

2.5 A Restatement of VARK

In this subsection I suggest a modification of the VARK theory. However, before I do that, I shall consider one more example from my own experience.

Let us go back to the concept of matching. What are the sides of matching? One party is learning preferences of the student while the other one is the teaching preferences of the teacher. Are they the same as learning preferences of the teacher? When formulating the concept of matching for the first time I deliberately omitted this issue for the sake of simplicity. This problem gets but a passing touch in [Fle95]: "Preferences for taking information in are not necessarily the same as preferences for expressing information to others though we have a shrewd hunch that they are linked."

My experience suggests an opposite "hunch". As I mentioned above, I believe I have a strong reading preference for taking information in. However in my teaching I rely heavily on diagrams and drawings. My slides and lecture handouts are full of them[8]. A possibility to express a particular concept by means of a picture always makes me very happy. My classes often have the following pattern: I put a slide with a diagram on the OHP and then discuss

[8]I am particularly grateful to authors of computer science textbooks who put pictures from their book on-line and make them freely accessible; for example, see [Tan01] and the accompanying web site `http://www.cs.vu.nl/~ast/`. My lectures have no doubt taken great advantage of these pictures.

this diagram with students. I find this pattern very convenient; on the other hand I cannot say that these pictures were equally important for my own understanding when I was learning the subject. Thus I conclude that I have the reading preference as a student and the visual preference as a teacher.

Learning and teaching are just two situations. It is natural to assume that there is a whole range of other situations not reducible to teaching and learning. Apparently we should speak of a multitude of preferences.

At this point I would like to suggest a major shift of terminology. Let us speak of *abilities* or *skills* instead of *preferences*. VARK preferences refer to modes of manipulating information. Let us therefore consider abilities to use a particular channel of information exchange in different situations to achieve particular goals. A learning preference is thus a preference to use a particular ability for learning. It is only natural then that in people like me teaching mobilises a different ability and occurs through a different channel.

Different channels were developed during different stages of the development of the humankind. The visual channel is the oldest; the development of reading/writing channel is a more recent achievement.

A learning style questionnaire thus tests what channels a person is happy to use for learning. It is only natural that most people are classified as being multi-mode, i.e., proficient in using different channel. A strong preference towards one channel is an extreme case and it suggests that other channels are blocked or underdeveloped.

Can abilities change? The very terminology suggest that they can be developed or acquired. Let us look at the student-centred and teacher-centred approaches from this point of view. The essence of the teacher-centred approach is that a teacher can diversify their teaching range, i.e., learn to use various media for teaching. I believe it is equally possible for a student to learn to use different channels for learning. The traditional VARK sends a humanistic message to students who can now say, "I'm different; not dumb", as the title of [Fle95] suggests. The message my interpretation sends is different but perhaps more useful: "You can develop yourself; you can open up new horizons for yourself".

The student-centred approach is thus faced with one serious dilemma. Teaching a student tricks how to use a particular channel at the expense of others may offer them a short-term bonus but a long-term disadvantage (this dilemma is briefly mentioned in [Fle95]). The attitude taken by the creators of LSQ appears to be better: they provide techniques for both using a strong preference and developing others. The ideal of a "rounded learner" suggested

by them is more appealing.

As far as teachers are concerned, it is still a good idea to use a range of methods relying on different channels of information exchange. This may lead to deeper and quicker understanding and this is particularly important in the extreme cases, e.g., dyslexia in learners.

I shall finish this section by one more example from my own experience. I used to underestimate the importance of the aural channel for exchanging scientific information. As I said before, I learned little from lectures. The same applied to talks at scientific conferences. However several years ago I found myself in a situation when I had to collaborate with a colleague heavily relying on this channel. He tried his best to involve me into discussions. At first I avoided discussions considering them a waste of time and effort. Only complete, finished results, in my opinion, could be communicated (and preferably in a written form). "How can we discuss this now? I should think it over first!" I used to say. Talking appeared to me to be of entirely recreational value.

However as time progressed I learned to use discussions. It was a "sink or swim" situation and I, quite unexpectedly for myself, developed an ability to swim. We formed a mighty research partnership and published a number of papers together. All these papers literally came to being over a cup of tea.

3 Applications for Computer Science

In this chapter I shall discuss how the principles of learning style can be applied to teaching of computer science. Despite the ideas I suggested above, I shall retain the traditional learning style terminology to emphasise the independence of this discussion from my proposed restatement of VARK.

3.1 VARK and Computer Science

What use can a computer science educator make out of learning style theories? As I mentioned above, the practical applications of learning style theories can be put into one of the two groups, those relying on the teacher-centred and relying on the student-centred approaches. Student-centred approach, i.e., the promotion of meta-cognitive awareness among students, is not really discipline-specific. That is why I shall ignore it in this chapter and concentrate on the teacher-centred issues.

Let us follow the method that should be used in the "ideal world" and hand out an ideal questionnaire to an (ideal) group of computer science students. What return are we likely to get? I believe that the result will exhibit a considerable kinaesthetic preference, or at least, following the restrictive "abilities" terminology, a preference to use the kinaesthetic channel for learning computer-related topics.

What are my reasons for saying so? Let me present a number of arguments drawn from academic experience.

One of the key elements of the curriculum at my department is the third-year project. The mark for the project has a predominant weight in the final degree assessment, and this practice has deep reasons behind it. Evidence shows that students actually *like* their projects. The standard course questionnaires handed out to project students return a lot of positive comments. Many students claim the project to be the most enjoyable part of their university experience. Not surprisingly, the average mark for the project has for a number of years been higher than the average marks for regular courses assessed by means of exams.

The second argument comes from my experience as an admissions tutor. Personal statements of computer science applicants nearly always contain references to experience of practical work with computers. One may argue that claiming such an experience is only natural for someone trying to secure a place on a computer science degree programme. I can continue this argument further though. When interviewing prospective students, I always ask them the question, "Why would you like to study computer science?" (This is a part of the routine and this question is suggested by the standard departmental interview form. The answer does not usually have any influence over the decision concerning acceptance, the whole question serving rather the psychological purpose of engaging the applicant in a conversation.) I cannot recollect a single instance when an applicant would answer something like, "When I was 12, I read a great book about computers and I have been fascinated by them ever since". By contrast, I have heard a lot of stories similar to, "At the age of 12 I got my first computer. It was very primitive, but I did wonderful things with it!" The applicants always enjoyed telling stories of this kind. For many of them "the first computer" really meant a lot. Practical experience has had dominating influence over most of them.

Many applicants claimed they wanted to get a computer science degree because of job prospects it offered. Such an answer (having the benefit of honesty) also indicates a certain degree of inclination towards practical issues.

The teaching of computer science has always relied heavily on examples, exercises, and practical sessions. The introduction to nearly any computer science book chosen at random will contain at least a couple of sentences emphasising the importance of practice in learning. As [KR88] puts is, "we believe strongly that the way to learn a new language is to write programs in it"[9]. The author of [Str00] says, "I occasionally present a concept briefly at first and then discuss it in depth later. This approach allows me to present concrete examples before a more general treatment of a topic. Thus, the organization of this book reflects the observation that we usually learn best by progressing from the concrete to the abstract – even where the abstract seems simple and obvious in retrospect." Such an approach relying on concrete examples (of programs) should be most appealing to someone of kinaesthetic preference.

This evidence points out at kinaesthetic preferences of computer science students. Note that this conclusion is not limited to VARK; the LSQ model also contains the "Activist" and "Pragmatist" categories of learners dominated by practical experience. Thus a similar conclusion concerning computer science education can be shared by supporters of different frameworks.

3.2 Computer Science Teaching Methods

The conclusion I have come to is not particularly counterintuitive. The teaching of computer science has always relied on practice in a striking contrast to the reading culture that comes as standard in the academic world. As a rule, computer science departments do not even have a reading week[10]. Let us consider this in more detail. In this section I shall discuss various ways of incorporating practice into teaching of computer science with an emphasis on practices used at my department and by myself.

Computer science is a relatively new discipline. It is about fifty years old; what a difference with mathematics, which has been taught for several thousands years! The computer science curriculum has been rapidly evolving. Something that came as standard some fifteen years ago may be completely obsolete nowadays. Similarly, as [MA03] points out, there is no universal consensus as to what should be taught, i.e., what should constitute

[9]Besides, I believe [KR88] to be a model computer science textbook. Being a natural reader, I owe a great deal of my knowledge of programming to it.

[10]I would be glad to swap the support this observation gives to my theory for an actual reading week though.

a computer science curriculum. The brief history of computer technologies provides numerous examples of ridiculously wrong predictions. Thus there is no clear understanding of what computer science graduates will find useful for their careers.

A computer science teacher may though use the wider experience of related disciplines. The closest of them are mathematics and engineering. Although computer science academics (including myself) often come from mathematical background, the engineering perspective seems to be more relevant, as the term "software engineering" suggests.

Teaching of sciences and engineering has always included a practical, experimental component [Ove03]. How can an experiment be carried out? First, it can be incorporated into a lecture. Lectures on physics and chemistry have always included a demonstrational element. This is still true for computer science. The equivalent of an experiment in a computer science lecture is a demonstration with a (laptop) computer and a data projector. I found this method particularly useful when teaching UNIX shell scripts as a part of the Operating Systems course. I could show the students how model scripts worked and also introduce changes "on the fly" (e.g., in response to a query) and show the immediate effect.

Of course, this is not a substitute to the proper "hands on" experience. Science courses always included laboratory sessions and computer science is no exception. A laboratory session may occur in a pre-structured environment, when students are told what exactly they are supposed to do and in what order. At my department this kind of sessions is referred to as "tutorials". Tutorials are usually given by postgraduate students to small groups. A session may also be organised in an unstructured way. Such sessions are referred to as proper "lab sessions". During such a session students can do their own work, e.g., experiment with examples given in lectures or do the coursework assignment. There is someone around to supervise their work though, i.e., to provide help when necessary. Sometimes such sessions are supervised by postgraduates and sometimes by lecturers themselves. I set up a number of sessions of this kind to help students to do coursework assignments for the Operating Systems course.

It must be noted that organisation of an unstructured session is much easier in computer science than, say, in chemistry because of safety issues involved. No chemistry department can really allow twenty-four hour access to its labs for students. In computer science this comes as standard. There are some safety problems in computer science too (I am referring to problems

of computer security) but they can be resolved by a qualified administrator and do not require constant monitoring.

Another way of incorporating practical experience is various kinds of projects. I have already discussed the third-year project, where a student is assigned to a supervisor and carries out some independent piece of work. Nearly every regular course is supplemented by the so called coursework assignment, which is a mini-project. In one of the second-year courses, the core programming course, the coursework assignment is particularly important. Students do pieces of a big project in groups and then "sell" them to each other at a "fair". This course simulates a real industrial environment. Apart from purely technical things it teaches students elements of practical "wisdom" (see [MA03]), e.g., interpersonal skills and ethical issues.

The last element is work-based projects. Good students can apply for a year in industry between the second and the third year. They get assigned to companies where they do real work and, besides, earn money. The department still supervises them to ensure they get tasks of educational value.

3.3 Failures

As the previous section suggests, a typical computer science department has a range of methods in store. But what if they all fail?

As [MA03] puts it, "The cognitive difficulties in learning to program and the skills that make a good programmer are difficult to identify. Probably more time is invested in teaching programming than any other area of the discipline, yet students struggle as they try to master the skill. Many graduates of computer science are deemed to be deficient in the topic $\langle \ldots \rangle$". Computer science departments are also notorious for their drop out rate.

Judging from my experience, I can only confirm that some students fail to master programming. Some (very small) percentage of third-years do not enjoy their projects at all because programming remains a mystery for them.

I can try and explain it from the learning styles perspective. Those failing may be the students who are at odds with the kinaesthetic culture. Just as the reading culture in other academic disciplines discriminates against non-readers, the kinaesthetic culture in computer science may badly affect non-kinaesthetics. In a way I have experienced it myself. Coming from mathematical background and being a natural reader I found it difficult to adjust to the practical and experimental flavour of computer science.

What can be done about it? A natural suggestion is to write better books

and to develop other means of instruction. Numerous computer science books are published every year but most of them seem to be of poor quality. It is typical of a computer science book to be just a step-by-step instruction. A VARK reader or just a person with theoretical interests will find such a book most boring and will learn little. I believe that such a situation can in a way be attributed to the novelty of computer science discussed above. Hopefully our grandchildren will have more books like [KR88].

I, as a computer science teacher, can address the issue by diversifying the range of teaching methods. After familiarising myself with the learning styles theory I started using various teaching methods consciously. Now when I am aware of the implications different methods can have I can balance the use of technique appealing to students with different preferences.

Another way of addressing the problem lays in the meta-cognitive plane. Students should be taught either how to learn computer science using other "channels" or how to develop the kinaesthetic learning skills.

4 Conclusion

The study of learning styles is by no means complete and no learning style theory can be claimed to be final. However these theories appear to be a helpful instrument serving the needs of teachers and students. They allow us to analyse the process of teaching and learning and, particularly, to identify and formulate the problems and difficulties. I can only recommend to every educator to familiarise themselves with learning style studies. Even thinking of learning styles can be useful. I shall finish this paper with a quotation from [HM92]:

> Trainers too often assume that learners are empty buckets waiting to be filled up by the training method the trainer favours. The fact that the buckets are different sizes, and/or leak and/or are upside down is conveniently overlooked.

I would only like to add that, as constructivist theories of learning prove, (see, e.g., [FKM03]) learners are not buckets at all.

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