How Learning Styles in CS can Foster Inclusion of Visually Impaired Students

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Abstract—We present the results of a study of learning types of CS students. In computer science education there seems to be a prevalence of visually oriented teaching methods. However, as the results of our investigation show, the learners may not actually benefit from this trend. This is valuable information in the context of including visually impaired learners in computer science classes - since these learners suffer the greatest disadvantages from visually oriented teaching and learning aids. Our results indicate that a different approach to CSEd placing more emphasis on kinesthetic and textual material may be of advantage for all CS students alike and also foster the inclusion of visually impaired learners.

I. INTRODUCTION

As part of the United Nations Convention on the Rights of Persons with Disabilities the ratifying countries have voted that disabled people must be provided with an integrative and cost-free system of high-quality education. In particular, disabled people must not suffer from a disadvantage concerning their educational perspectives due to their disabilities. When planning inclusive education, the subject-matter specific requirements as well as the specific personal needs of all participating disabled and non-disabled students must be known and taken into account. This is necessary to compensate for the special needs that arise from many disabilities without compromising the overall quality when teaching a specific subject-matter to a broader range of students. This is particularly important if students with a sensory disability attend lessons that are based on catering to this particular sensory information.

In this paper we are investigating to which extent a visual impairment of learners presents problems to computer science education (CSEd). Visually impaired students - obviously - have a disadvantage with regard to the assimilation of visual information. This may have an effect on their subsequent information processing and retention as well.

Such an investigation is particularly relevant for CSEd, as the prevalent use of computers and (usually visually oriented) modeling techniques (cf. [13]) puts an emphasis on visually presented information in CS classes or lectures compared to other subjects. This is even true for the more theoretical aspects of CS: “As students and teachers alike, we tend to rely heavily on diagrams to aid us in comprehending and working with linked lists, trees, and graphs.”[2]

This prevalent use of visual teaching aids makes only sense, however, if the typical CS students are also visually oriented with regard to their preferences or learning styles. We have been trying to find out, whether or not this is case and whether, therefore, the inclusion of visually impaired students in CSEd is inherently difficult or not. If the typical CS student has a preference for visually presented information, an integrated education of regular and visually impaired students will be next to impossible to design without sacrificing quality for either group. If the typical CS students does not have a preference for visually presented information, however, it is questionable to put so much emphasis on it in teaching. We present the results of an investigation among CS students regarding their learning types. As the results show, there is no clear indication that CS students are preferring visually presented information over other types.

II. THEORETICAL BACKGROUND

A. Learning Styles

There are several different ways of defining learning styles. Since we are focusing on the assimilation of information, we have based our studies on the VARK model of learning styles of Fleming and Mills [10], since this seems to be the most established model concerning differences in information assimilation. As described in [10], the model is explicitly based on the work of Stirling [22], who - in the context of neurolinguistic programming (NLP) - distinguished between the three perceptual modes “aural”, “kinesthetic” and “visual”.

The aural learning style is described by a preference for “heard” information [10]. Persons of this type learn usually well by attending lectures, seminars or discussions.

A kinesthetic learning style in contrast is not bound to one particular sense: “For the questionnaire it was defined as the perceptual preference related to the use of experience and practice (simulated or real). In that sense it is not a single mode because experience and practice may be expressed or taken in using all perceptual modes - sight, touch, taste, smell and hearing. However, a kinesthetic teaching experience is defined as one in which all or any of these perceptual modes are used to connect the student to reality, either through experience, example, practice, or simulation” [10].

The visual learning style of the NLP model is - according to [22] - not specific enough, as it encompasses two types of information that can be assimilated visually: “The first preference includes diagrammatic material often used by teachers to symbolize information (e.g., graphs, charts, flow charts, models, and all the symbolic arrows, circles, hierarchies and other devices used by teachers to represent what could have been printed information). Second, there is information that is largely composed of printed words from which some students appear to get a greater or lesser degree of understanding” [10].

Based on this, a visual learning style is defined by a preference for graphically or symbolically represented information,
while a newly introduced “read/write” learning style is defined by a preference for written (verbal) information.

Therefore, according to the VARK model, the four possible learning styles are: (V)isual, (A)ural, (R)ead/write, and (K)inesthetic.

However, typically, a person is not exclusively one type: “Of course no student or teacher is restricted to only one mode for intake but, even so, it is noteworthy that there are some dominant preferences [...] and some voids [...] among different students” [7]. Instead, a learning style is defined as “a collection of preferences for the ways a learner receives information” [7].

The learning style of a person is important with regard to teaching: “Information that is accessed using strategies that are aligned with a student’s modality preferences is more likely to be understood and be motivating. [...] The use of learning strategies that are aligned with a modality preference is also likely to lead to persistence learning tasks, a deeper approach to learning, active and effective metacognition. [...] Knowledge of, and acting on, one’s modal preferences is an important condition for improving one’s learning” [8].

In particular, learning styles in an educational system could have profound impact on the system itself. A hypothesis described in [7] postulates, that the current educational system has a bias in favor of read/write learning styles that tends to reproduce itself, since “students who favor reading succeed in such a system and become teachers themselves [...] so many university teachers are clones of the read-write teachers who taught them.”

For the sake of completeness it should be mentioned that in the last three decades numerous - more than 70 - other systems of learning styles have been described [4]. However, in contrast to the VARK model, nearly all other theories (e.g. [15], [12], [6]) focus on the processing and not on the assimilation of information. Since it can be assumed that a sensory disability does first and foremost affect the assimilation and only indirectly the processing of information, it seems reasonable to use the VARK Model for our purposes however.

B. Prevalence of visual information in CSEd

Without claiming completeness, we are focusing on three aspects of CSEd that should underline the omnipresence of visualization - or put otherwise: the need of assimilation of visual information - in computer science teaching.

First, in CSEd we have the (in general favorable) situation that teachers can use computers or other hands-on devices (e.g. robots [5]) as teaching aids that the students can actually work with. However, as soon as there are less devices then students - and the students have to work in groups - some of them will have to rely on learning through observation only.

Next, CS itself is inherently built upon visualizations. As noted in [2], diagrams are especially used in computer science teaching as a tool to foster understanding. Also, many problem descriptions are using visual media like sketches, illustrations or animations [3]. Clearly, a sole reliance on visualizations are posing a problem to visually impaired people, as significant information is transported by visual means only [18]. Also, visualization in CSEd is often not just a teaching aid but the topic itself, since modeling if inherently coupled with visual representations that are later also required in the jobs of computer scientists: “Moreover, it is an asset to know UML when searching for a qualified job” [18]. The following six aspects are fundamentally difficult for visually impaired people when working with visualization techniques: “They need to (a) know the visual shape of the diagrams, (b) understand the semantics of the visual representation, (c) learn an alternative way to design the different aspects of the diagrams, (d) be able to construct the diagrams themselves, (e) communicate with their fellow students and lecturers about the topic and map the descriptions of sighted people to their alternative language for UMLs, (f) learn how to translate the UMLs into programming code” [18]. Particularly for UML, a solution, as suggested in [18], might be, to use haptic tools to foster understanding of diagrams. Based on this, textual representations could be taught to visually impaired people which can be translated into “correct” UML diagrams by automatic means. However, as noted in [17], such a text-based approach cannot life up to the complexity of visual representations in software engineering: “Traditional text based source code is accessible to blind people using assistive technology (i.e. screen readers). But the emerging rich visual presentation within software engineering causes many barriers.” A proposed alternative might be the use of haptic graphical displays.

Finally, visualizations are used as mere teaching aid in other areas of CSEd, for example algorithmic visualizations (AVs). “Good AVs bring algorithms to life by graphically representing their various states and animating the transitions between those states. They illustrate data structures in natural, abstract ways instead of focusing on memory addresses and function calls” [21]. In [1] an attempt was made to show that mostly visual learners benefit from AVs, however, that result showed exactly the opposite, namely that “reflective and verbal learners outperformed active and visual ones” [1]. The research results regarding the usefulness of AVs are not clear cut. Several studies are pointing towards the usefulness of using AVs in teaching [21].“The true value of using visualizations may lie not in their content but rather in their serving as a motivational factor to make students work harder. Our results show that learning increases as the level of student engagement increases. AV has a bigger impact on learning when students go beyond merely viewing a visualization and are required to engage in additional activities structured around the visualization” [11].

III. Methodology

A typical way to identify the learning styles of persons is to use existing questionnaires in a form of self-assessment. The VARK test based on [10] has the advantages that it is of manageable size and is also available in other languages (in our case German)\(^1\). The German version consists of 13 items. Each item starts with the description of short real-life scenario and then offers a choice of four possible responses to the situation. It is possible to select more than one response. The four responses are corresponding to the four different learning styles of visual, aural, read/write or kinesthetic.

\(^1\)The test is available online at: www.vark-learn.com
test is evaluated by summing for each of the four learning styles, how often the corresponding answer was chosen by a participant (called the “preference score” for a learning style). If there is a clear maximal value among these four preference scores, the participant is said to have a monomodal learning style. If several of the scores are equally maximal, the learning style can also be bi-, tri- or tetramodal (this is also called the “VARK learning style”).

The reliability and validity of the VARK test has been investigated in [16]. According to the results, the test can be assumed to be both reliable and valid, however: “Potential problems related to item wording and the scale’s scoring algorithm were identified, and cautions with respect to using the VARK with research were raised” [16].

In our study, we use this test to identify the learning styles of CS students, based on their response pattern to each item. Therefore, the problems concerning the evaluation algorithm described in [16] are of less concern. In contrast to the original method, we attributed a person to a monomodal learning style only if the maximal preference score had a difference of at least 2 to the next higher value (the original method uses a distance of only 1). The same goes for bimodal learning styles, where we used a distance of at least 2 to the next (third) highest value. So, our method is stricter concerning the monomodal and bimodal learning styles.

A. Data collection

The (anonymous) survey was taken among all students at the CS department of our university who are currently in the first four semesters of their studies including students that have only currently begun their studies (the survey was done at the beginning of the winter term). We invited the students to take part in the survey by e-mail. In total, we had 484 usable results. In order to better evaluate the data, we asked for the following information from the participants:

1) Gender
2) Major (either CS, Games engineering, Business informatics, or Business studies)
3) Their average grade so far (they could choose between four different ranges of their grades).
4) The final grade of their secondary school education (using the same four ranges of grade).
5) Their frequency of attending lectures (using a six item scale of “always”, “most times”, “often”, “sometimes”, “seldom”, and “never”).
6) Their frequency of attending problem sessions (using the same six item scale as above).

IV. RESULTS AND DISCUSSION

Table I shows the distribution over the different learning styles. We were investigating whether or not there are inherent differences in the groups that can be naturally formed in the data based on gender or major. We found that there is no significant difference between the different majors (using a chi-square test). This remains true, even when only using the monomodal learning styles for analysis, as the multimodal types may interfere with the results.

It is interesting to note, that the kinesthetic type is the strongest of the monomodal types. Also, when looking at the bimodal types, the combination of aural/kinesthetic and kinesthetic/visual are the two most frequent occurrences. The monomodal visually oriented learning styles are the smallest subgroup comprising only 6% of the students.

Next, we were investigating how the attendance of lectures and/or problem sessions may correspond with the learning styles. To this end, we aggregated the two highest and the two lowest options in the six item scale (see above) and ignored the ones in the middle. While a chi-square test reveals that there are no significant differences, this may be due to the low numbers in each of the groups - for example, there are only four participants who are of a monomodal visual learning style and who are also frequently attending lectures. Without considering significance, it is at least interesting to see that there are roughly two times as many aural, read/write, and kinesthetic types who are frequently attending lectures when compared to the rest. Concerning the problem sessions, almost 90% of the participants are frequently attending them, so there is no influence of the learning style to be expected. Consequently, none was found.

Concerning the grades, we also compared only the two extreme categories, comprising the grade 1.0 to 1.4 and 2.5 to 4.0 in a grading system ranging from 1 (very good), over 4 (passed) to 6 (insufficient). Again, there were no significant differences found between the learning styles of good, mediocre, or bad students.

Fleming presents the summarized results of more than 20,000 evaluated VARK questionnaires [9]. This data has been collected by using the online survey. Fleming offers proportional distributions for different attributes like gender, professional group and age. For the professional group “Computing” (n = 754) the following distribution of the monomodal learning styles is given: V=22.4%, A=22.5%, R=26.0% and K=29.1%. The summarized distribution of all 20,254 participants (V=21.7%, A=24.5%, R=24.9% and K=28.8%) differs only slightly from this group.

When using these numbers to judge the quality of our findings, we can see that the results are very similar. In our study, 49% of the participants are of a more than bimodal learning style, in [9] it is 48%. Concerning the bimodal learning styles, due to our stricter method of attributing the preference scores to learning styles we only have 8% in contrast to 15% in [9]. For monomodal learning styles, we interestingly get a higher percentage (43% as opposed to 37% in [9]) even though our method is stricter. However, as the populations are not fully comparable between the studies a certain deviation is to be expected. The order of the monomodal learning styles is then in accordance with the results of [9] again. In both studies the kinesthetic type is the most dominant one, followed by the read/write type, the aural type and the visual type. Taking these results as well as the relatively high number of respondents into

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TABLE I. DISTRIBUTION OF THE DIFFERENT LEARNING STYLES OVER ALL PARTICIPANTS. BI AND MT ARE COUNTING THE BIMODAL LEARNING STYLES AND THE TYPES WITH MORE THAN TWO MODES, RESPECTIVELY.
account, we don’t expect that there are biases due to small sample size in our results.

What do these results imply for CSEd and inclusive education of visually impaired learners?

Taking a look at the results themselves, first, it is obvious that there is no clear dominance of visual learning styles among the CS students that took part in our survey. Instead, the “typical” CS student is of a kinesthetic type. This has also been hinted at in [14]: “I believe that the result (CS) will exhibit a considerable kinaesthetic preference, or at least [...] a preference to use the kinaesthetic channel for learning computer-related topics.” Whether or not the identified dominance is “considerable” remains open. In contrast to the results of [9], the CS students show a relatively higher amount of visual learning styles and in turn a fewer number of read/write types.

So, based on our results and on the underlying theory behind the VARK model, the perceived dominance of visually oriented teaching material as presented above cannot be justified with the learning preference of the students. To the contrary, it seems advisable to use teaching and learning aids that particularly cater to the kinesthetic and read/write learning styles.

It is positive to note that none of the attributes that were investigated seems to have any influence on learning styles. This, in particular, also means that the current university system does not seem to favor a certain type of learner - otherwise this should have shown in the dependence on the grades that we analyzed above.

Following the context of our investigation it does seem as though CS students show a relatively higher amount of visual learning styles when compared to the population of [9], however, the absolute amount is still rather small. So, teaching in an inclusive educational system with visually impaired people seems to be possible in CS as there is no indication of a negative impact (in general) concerning the sensory preferences of the students for visual information.

What is of major importance for all of this is the separation of the read/write learning style from the visual learning style as suggested by [10]. As has been noted above, the reading of Braille and the reading of regular type involve the same regions of the brain. This means, that a read/write learning style - based on its definition and close to the definition of the kinesthetic type - cannot be bound to a particular sensory modality. Instead, it is most probably simply based on a person’s ability to employ words and textual representations in thinking and learning. This is encouraging for the inclusive education, as this ability - given suitable support in their primary education - is not dependent on the visual capabilities of a person. Therefore, catering to the read/write learning styles in CSEd seems promising to foster inclusion of visually impaired learners.

A. Detailed analysis of the VARK items

In a next step, we analyzed the responses to the single items of the VARK test in more detail. To this end, for each of the response options for each item it was judged by a visually impaired person whether or not this option is feasible for visually impaired persons. It was then checked whether a significant amount of students chose this option(s) in their responses. We present only the most interesting items here along with a short discussion of the implications. The item numbers used in the text correspond to the numbering of the German version of the VARK test, the item text itself, however, is taken from the corresponding item of the English version, which may have a different number. The original item description and the the response options are given - problematic options are set in italics. Also, the percentage of the participants that chose each option is given. In general, each option that corresponds to the aural learning style is deemed as not problematic for visually impaired persons. Also, read/write response options are usually not problematic as long as the necessary material can be taken to be available in digital (or otherwise suitable) form.

Item 1:

You are helping someone who wants to go to your airport, the center of town or railway station. You would:

- draw, or show her a map, or give her a map 32%
- tell her the directions 47%
- write down the directions 7%
- go with her 14%

Almost half of the participants have opted for the oral explanation. The second most frequent answer, however, includes using a plan which is problematic for visually impaired persons. More generally, the first response option includes a visualization.

Item 2:

You don’t know if the correct spelling of a word is “‘imediate”’ or “‘immediate”’. You would:

- look up the word in a dictionary 51%
- Imagine both words figuratively and decide accordingly 18%
- Imagine the sound of both words and decide accordingly 11%
- Write down both word by hand and decide accordingly 19%

Using a dictionary is (in general) not problematic for visually impaired persons. This option was the most frequently chosen one. The next frequent option of writing down both words and checking the spelling visually is interesting insofar, as according to [20] and [19] reading Braille activates the same brain regions as reading regular type. So, it can be assumed, that this option is not problematic for visually impaired persons.

Item 4:

You are going to cook something as a special treat. You would:

- cook something you know without the need for instructions 27%
- look on the Internet or in some cookbooks for ideas from the pictures 37%
- use a good recipe 36%

In this item, the most frequently chosen option is one that is typically problematic. The general idea of “browsing” that is described here is typically based on a series of visual impressions that are used for a decision making process. If the visual impairment is severe enough to make this impossible, such a decision making process is most probably impossible - as it remains questionable whether an aural or textual
description of the same visual information is amounting to the same.

Item 7:

Remember a time when you learned how to do something new. Avoid choosing a physical skill, eg. riding a bike. You learned best by:

- diagrams, maps, and charts - visual clues 11%
- written instructions - e.g. a manual or book 6%
- listening to somebody explaining it and asking questions 21%
- try it by myself 62%

This item is particularly interesting for our chosen context. As described above, CSEd is heavily reliant on the first option - which was only chosen by about 11%. This option is also the only one that is problematic for visually impaired persons. Instead, the majority has chosen the “Trial-and-Error” approach to learning, which is in general very closely related to learning (especially) programming.

Item 9:

You want to learn a new program, skill or game on a computer. You would:

- use the controls or keyboard 91%
- read the written instructions that came with the program 5%
- talk with people who know about the program 3%

This item is closely related to Item 7 above. The “Trial-and-Error” approach is here also favored by the majority. Also, none of the options was deemed problematic - indicating that a “visual” learning style is not completely reduced to actually having the ability to see.

Item 10:

You want to visit a friend but you don’t know the way. You would like:

- to get a drawn map 42%
- to get an oral description 35%
- to get written description of the way 19%
- to be picked up by the friend 4%

This item seems closely related to the first item. But instead of giving an explanation, in this item one received an explanation. What has been stated for the first item holds for this item as well. What is interesting to note is the discrepancy between the response frequencies concerning a textual information (that 19% would wish to receive, but only 7% would use when explaining) and using a plan (42% would wish to see a plan but only 32% would use one for explaining).

Item 13:

Do you prefer a teacher or a presenter who uses:

- handouts, books, or readings 29%
- diagrams, charts or graphs 36%
- demonstrations, models or practical sessions 22%
- question and answer, talk, group discussion, or guest speakers 12%

Finally, for this item, again, the problematic option of using diagrams and other visualizations was chosen most frequently by the participants. Since this is the only problematic option however, this also means that almost two thirds (64%) have chosen an option that is not problematic for visually impaired persons.

V. Conclusion

All in all, our study shows that an inclusion of visually impaired learners in computer science education is a promising, albeit not easy approach. While there is currently a prevailing theme of using visualizations both as content and as teaching and learning aids, the learning styles of CS students does not seem to require this. Also, it is not necessary to completely avoid all forms of visualizations in an inclusive education. For example, the missing of algorithmic visualizations may not present a major problem for visually impaired learners, since it can be assumed that the AVs are closely following an algorithmic description in a textbook, otherwise the visualization is more misleading than useful [11]. Such a description can present a viable alternative to AVs for visually impaired learners.

If the theory behind the VARK test and learning styles is deemed valid, CSEd should best adapt to the identified dominance of kinesthetic and read/write learners - which in turn would also favor inclusion of visually impaired learners. If these adaptions are in the form of additional learning and teaching aids, nothing is “lost” from the current state of CSEd, but a lot could be gained from it.

It is interesting to see that the CS students show a (relatively) higher percentage of visual learning styles. While it does not seem plausible that these learners are particularly drawn to CS, it may be the result of the described dominance of visually oriented teaching methods. If this were true - i.e. a particular style of teaching - fosters a development regarding the preference of the learners, even more caution (not only in CSEd) must be placed on the teaching and learning methods and care must be taken to include as many different accesses as possible.

REFERENCES


