Autism

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Autism: Implications for Inclusive Education

with respect to Software Engineering

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ABSTRACT

Within Computer science and Software engineering, the prevalence of students with a diagnosis of autism spectrum disorder is relatively high. Ideally, education should be inclusive, with which we mean that education must be given in such a way that additional support is needed as little as possible.

In this paper, we present an overview on what is known about the cognitive style of autistic individuals and compare that cognitive thinking style with computational thinking, thinking as an engineer, and with academic thinking. We illustrate the cognitive style of autistic students with anecdotes from our students.

From the comparison, we derive a set of guidelines for inclusive education, and we present ideas for future work.

CCS CONCEPTS

• **Social and professional topics** → **People with disabilities**; • **Applied computing** → *Education.*

KEYWORDS

Autism, Inclusive education, Cognitive thinking style

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1 INTRODUCTION

Inclusive education will only work when education benefits *all* students, as opposed to education for who is not disabled, with additional programs for the disabled [54]. This statement has implications for software engineering education with respect to autistic students. In this paper, we explore these implications.

Need for inclusive education. The prevalence of autism continues to rise. In the USA for instance, between 2000 and 2014, the prevalence of autism increased from 1 in 150 (about 0.67%) to 1 in 59[1] (almost 1.7%). It is difficult to interpret these numbers, because there is no standardization of autism survey methodology. Also, it is an open question whether autism is more often diagnosed because of shifting definitions, because of more attention, because of a society that becomes more difficult to live in for who is autistic, or because there are more environmental factors that cause autism. The rising prevalence of autism is probably due to the rising numbers of individuals with high functioning autism, who are most able to go to university [66]. We may therefore conclude that we will continue to see a rising number of university students with a diagnosis in the autism spectrum.

Students with a form of autism often need support to achieve success at universities, while they do not lack intellectual capacities [11]. In the US and Australia, youth with autism have the highest risk of being completely disengaged from any kind of post-secondary education or employment [43]. Compared with other disabilities, youth with autism have the lowest rates of employment and education participation. Similar figures were found in Sweden and Canada [43]. These figures are even more startling when one realizes that one of the theories about autism is that it represents high, imbalanced intelligence, a 'disorder of high intelligence' [12]. Moreover, IT companies begin to see the advantages of autistic personel [2]. Therefore, it is really worthwhile to investigate how we can make education more inclusive with respect to autistic students.

More and more, autism is seen as 'being different' as opposed to a disorder [28]:

> In our opinion, high-functioning autism should neither be regarded as a disorder or a disability nor as an undesirable condition per se, but rather as a condition with a particular vulnerability. Autism can also have desirable and enabling consequences, both to the individual and to society.... For what are now disabling traits of these people, may, in a differently constructed social environment, become 'neutral' characteristics.

Inclusive education that helps autistic students, therefore, is not only needed because of the rising number of autistic students (who really need support of some kind), but it would have benefits for

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[1] https://www.cdc.gov/ncbddd/autism/data.html

[2] see, for instance *CEO's finally get it. Staff on the autism spectrum are a huge asset*, Wired, https://www.wired.co.uk/article/companies-employing-autistic-individuals

all: inclusive education would promote a specific kind of diversity, and diversity has a positive outcome on cognitive skills for all students [7]. This need for diversity has, for instance, also been explained with respect to personality type [10, 62]). Especially important is that successful teams show diversity in personality [46].

With respect to diversity, we want to stress that increasing the possibilities for autistic students to successfully finish their studies does not have a negative impact on the number of women, in our opinion. The low number of women in Computer science has been attributed to the 'masculine culture' that Computer science has been 'drenched' into [15]. This 'male culture' is often associated with autism [29]. The diagnosis of autism however, is itself heavily 'gendered', in such a way that researchers payed much attention to everything considered 'male', discarding everything considered 'female' [29]. As a result, more males received a diagnosis, and a sex ratio with far more males than females was considered the 'natural' ratio. More and more, implicit biases in the process of diagnosing and measuring autistic traits have been made explicit, and more and more, women are diagnosed too. The ratio male-female is now considered to be 2:1, and still, autistic females may be missed by current diagnostic procedures, which would bring the 'real' ratio closer to 1:1 [50].

In fact, one could say that the same mechanism that associated Computer science with 'masculine' did associate autism with 'masculine', and both associations form a disadvantage for women. Therefore, we do not make Computer science more 'masculine' by addressing the cognitive style of autism in Computer science education. In fact, we hope to help in 'de-gendering' both autism and Computer science by the type of inclusiveness we adrress.

Cognitive aspect of inclusive education. Autism is characterized by a different cognitive style (which we elaborate on in Section 5). On the one hand, this different cognitive style has advantages. For instance, one can see an increasing demand for people within the autism spectrum, from, for instance, IT firms [3]. On the other hand, because Software engineering education is geared to a 'non-autistic' cognitive style, it might be more difficult than necessary for students with an autistic cognitive style to complete their education. A really inclusive education would be geared to both autistic and non-autistic students.

Mismatches between cognitive skills for Software engineering and the autistic cognitive style, often are skills that whoever is not autistic will take for granted. As such, they form 'blind gaps' that educators in Software engineering might have with respect to autistic students. With 'blind gaps', we mean to take a skill for granted (because non-autistic students often acquire that skill intuïtively), that should not be taken for granted (because for autistic students, it takes explicit effort to acquire that skill). In this paper, we take a theoretical approach to detect these 'blind gaps'. To count as inclusive, education should cover these 'blind gaps'.

In this paper, we only analyze *cognitive skills*. Excluded from our attention here, is, therefore, support with independent living and social skills, with planning and time management, which is often attended to by universities [59]. We also exclude attention to cooperation, because we think that cooperation in education for students in the autism spectrum deserves a separate study.

Our goal is to create a set of guidelines for inclusive education for students within the autism spectrum, based on the differences between the cognitive style that characterizes autism and the cognitive style that is needed within Software engineering.

Structure of this report. This report is structured as follows. In Section 2, we give a short introduction into autism (as we will explain, we use 'autism' as a synonym of 'autism spectrum disorder'), and about the prevalence within Software engineering. We explain our research method in more detail in Section 3. Section 4 contains related work, about support for autistic students in general.

We characterize the autistic thinking style in Section 5. In Section 6, we compare the thinking skills that are needed within Software Engineering with the autistic thinking style that we established in Section 5. We show which of those skills might form a hindrance for autistic students. We illustrate some of these findings with anecdotal evidence that we have gathered from our students.

Section 7 describes the guidelines we derive from the comparison. In Section 8, we discuss the explorative nature of this paper, and argue why our exercision is worthwhile. In Section 9, we draw our conclusions and present ideas for future work.

2 AUTISM, BACKGROUND

Autism is described in the Diagnostic and Statistical Manual of Mental Disorders (DSM) as a pervasive development disorder [14]. Diagnostic criteria are persistent deficits in social communication and social interaction, and restricted, repetitive patterns of behavior, interests, or activities.

Autism, Asperger, ASD. Autism has been 'discovered' by Leo Kanner [32], although other people described similar characteristics earlier (in particular Hans Asperger [74]). At first, what Asperger and Kanner described has been classified as two different disorders, although within the same 'autistic spectrum': the Asperger syndrome and classical autism [72]. Later, more variants were discerned, such as PDD-NOS (Pervasive Developmental Disorder Not Otherwise Specified) or high-functioning autism (classical autism with normal to high intelligence). In the fifth version of the DSM [14], this distinction has been abandoned, because most researchers agree that the distinction is not useful. At this moment, one speaks of 'autism spectrum disorder' (ASD). When we speak of autism, in this article, we refer to ASD.

During the years, the diagnosis of autism (and with it, the meaning of the word 'autism') has seen major shifts in type of symptoms [63, 74]. The most recent shift is to view sensory and perceptual issues as the main characteristic [6, 27, 60].

Neurodiversity. Autism is described and treated as a psychiatric disorder and for a long time, research has been directed to both prevention and cure for autism. In recent years, a shift can be seen to view autism in individuals with average or above average intelligence not as a disorder, but as a difference, which nevertheless requires adaptations from the rest of society [33] (in the same manner as for, for instance, left-handedness). In other words, autism is, in this view, not seen 'as a disorder or a disability nor as an undesirable condition per se, but rather as a condition with a particular vulnerability and with particular strengths' [28]. This view of autism as a difference has a name: neurodiversity [44]. When we hold this view on autism, it becomes even more important to try to educate our students in such a way that autistic students have a chance to get their degree.

To avoid the contrast 'autistic' versus 'normal', that emphasises the abnormality of autism, many use the word 'neurotypical' for non-autistic persons. In this report, we will use that word too.

Prevalence in Software engineering. Individuals within the autism spectrum more often have a profession that requires technical skills than neurotypical individuals [57], and are more inclined to follow STEM (science, technology, engineering and mathematics) studies [66]. This fact makes it plausible that autism has a higher prevalence among Software engineering students than among the general public.

Measuring the prevalence of autism among students is difficult. It is not possible, for obvious reasons, to diagnose each student as part of an investigation. When one asks students whether they have a diagnosis, one misses those students who are autistic but never have been diagnosed, and one misses students who do not want to disclose their diagnosis.

In countries where students receive special education services when they have a diagnose of autism, one may measure the prevalence of those services. Based on this estimation, Wei et al. found a higher prevalence of autism in the STEM sciences than in non-STEM disciplines [66].

Other estimations are possible as well. There are, for instance, measurements of autistic traits, such as the Autism-Spectrum Quotient (ASQ or AQ) [5]. This measurement rates individuals relative to the mean of the population, with respect to autistic traits that are measured through a self-report questionnaire. The ASQ can be used as a coarse-grained estimation of the prevalence of autism. Note, however, that the ASQ is based on self-reporting, and as such cannot be regarded as an alternative to a formal diagnosis.

The ASQ has a normal distribution [53]. When depicting the ASQ in the form of a bell curve, people who are probably within the autism spectrum occupy a small portion of the extreme of the cuve. One half of all people have more autistic traits than average.

Using the ASQ on a population of university students, White et al. found that more than 50 percent of the high ASQ students where computer science majors. Of the students who did not score a high ASQ, only 28 percent were computer science majors [68]. We may conclude, therefore, that in general computer science students scorefairly high on the ASQ. Baron-Cohen found that computer scientists score higher on the ASQ than scientists in medicine and biology (and mathematicians score higher than computer scientists) [5]. This means that self-perceived autistic traits are more prevalent in mathematicians and computer scientists than in other scientists.

3 METHOD

Our goal is to derive a set of guidelines with respect to inclusive education. To do that, we compare traits of the autistic cognitive style with cognitive skills that are needed in Software engineering, .

Although there are many competing theories about autism, they agree on the general ideas about what the autistisc cognitive style is. It is, however, a difficult task to summarize the knowledge within such a vast field without delving into the details of all competing theories. In the first place, there are those characteristics of the cognitive style that can directly derived by the description in the DSM. Theories that try to explain autism, show how this theory explains various cognitive aspects of autism. Such cognitive aspects form part of the autistic cognitive style that belong to autism, according to experts. Finaly, one of the authors is a practitioner, with comprehensive experience as a therapist for autistic adults. She checked whether we were complete.

The autistic cognitive style that we present here is therefore grounded in how experts see autism.

During the past two or three years, students sometimes sent us a summary of the difficulties that they faced during their study, that, according to their idea, are associated with their autism. We cannot use these observations as 'proof', because they are anecdotical by nature. However, they illustrate the points we make very well, so we included them where applicable, to make some cognitive characteristics more clear.

Deciding the cognitive skills that belong to Software engineering is no exact science. As a start, we tried to find an operational model of computational thinking, because that would give us the most concrete means to compare aspects of cognitive thinking with the autistic cognitive style. We added thinking as an engineer and academic thinking to these cognitive skills. We can never be certain that we are complete, but at least we have a beginning.

4 RELATED WORK

In a systematic literature review, Gelbar et al. found that case studies in a university setting indicate the presence of anxiety, loneliness, and depression and the need for supports for autistic students. They also found a lack of studies indicating which support is needed, and what works [22].

Fleury et al. [19] inventarised what is known about Academic performance of students with ASD (Asperger Syndrome; the study was done before all forms of autism are called ASD, autism spectrum disorder). They found the following characteristics:

Reading Students with ASD were found to be quick in the mechanics of reading (recognising words), but in general have problems comprehending text.

Writing Hand-writing is often difficult for students with ASD. Also, planning and organising a text is a difficult skill for students with ASD.

STEM STEM studies are popular with students with ASD, in particular mathematics, science, and computer science. However, within these studies too, they face difficulties with language comprehension and executive functioning. Mathematic achievements for students with ASD ranges from modest weaknesses to mathematical giftedness.

They also inventarised instruction strategies for students with ASD.

Priming: Preparing a student in advance for what is coming, for instance before the start of the study, the start of a course, a task or a meeting.

Peer support: Peers are taught how to support students with ASD.

Video modelling: Examples of a skill that is taught are videotaped.

Explicit Strategy Instruction: Explicit strategies are given for a task (for instance, writing, or solving mathematical problems): routines to follow.

Self management: Students monitor their own behaviour and performance through self-tests.

Graphic organizer: A visual chart is used to organize a student's knowledge or ideas.

Facilitate skill generalization: To help generalization of a skill, a skill is trained in various contexts.

Kurth et al. found that students with autism have areas of strength in concrete, procedural academic tasks. They were less successful in performing abstract and inferential tasks, including passage comprehension, writing passages, and solving applied math problems (e.g. word problems). They also found that academic achievements of autistic students were better in an inclusive setting than in a special education setting [37] This means that adjusting the education in such a way that all students are able to follow (true inclusive education) works better than leaving education as it is and have separate additional classes for autistic students.

Twenty six university students within the autism spectrum were compared with 158 neurotypical university students (from various universities within the UK) in a study in which they were asked to self-report their strengths and 'challenges' [23]. The challenges mentioned by autistic students concerned the need for guidance and clear instructions, not knowing how to pace, absorption in one subject, processing time, organizational skills, attention problems, group work and supervisor relationships, visualising abstract concepts, motivation/procrastination, critical/creative thinking and research/data analysis. Theit strengths, as self-reported, were academic and critical writing, the ability to work long hours, to anderstand complex ideas, and memory.

When comparing students with and without a diagnosis of autism, autistic students' self-reported strengths more often contain [40]: attention to detail, logical reasoning, focus, systemizing, consistency, visual skills, creative solutions, retentiveness, repetitive tasks, numbers, auditory skills, and concentrativeness. Neurotypicals score themselves higher on organizing ability, verbal skills, emotional control, flexibility, social skills, multitasking, empathy and team work.

Strategy instruction has been proposed for students within the autism spectrum, for the subjects of reading, writing and mathematics. [67]. Strategies teach knowledge of procedures (i.e., how to do something). Strategy instruction teaches the rules, processes, or the order of the steps that are applied systematically that lead to a problem solution. Strategy instruction proved helpful, in these areas.

Interestingly, what is called strategy instruction resembles the procedural guidance that is proposed as helpful in general for software engineering education [45]. Here, we see that what is helpful for students with an autistic thinking style, might deliver better education in general.

5 AUTISTIC COGNITIVE STYLE

In this section, we try to define an autistic cognitive style, based on literature, to be able to compare that style with the cognitive skills that are related with Software engineering.

Autism can be characterized by a cognitive style [24]. Research in parents and siblings of autistic children suggests that this cognitive style has a normal distribution, with autistic individuals on the 'autistic' end, while the remainder of the distribution is 'neurotypical'. Neurotypical family members of autists, while in the 'neurotypical region', are close to the 'autistic region' of the bell curve [25]. That means that more people have an autistic cognitive style than only those with a diagnosis of ASD.

Weak Central Coherence. One of the characterizations of autistic cognitive style is 'weak central coherence' [21]. Strong central coherence means: being able to process information into a higher level meaning, at the expense of details. In contrast, weak central coherence means more attention to detail as to the whole. For instance, someone with ASD will in general be faster to spot a mistake in an architectural blueprint, and many people with ASD are especially good at software testing [65]. On the other hand, it will be more difficult for them to grasp the essence of a text.

Recent research suggests that weak central coherence in autistic people is not a global processing deficit, but a local processing bias: when permitted free choice, they show a reduced preference to report global properties of a stimulus, but when they are instructed to report global properties, they are as able to do so as neurotypicals. A better description of 'weak central coherence' is, therefore, preference for local processing ('strong local processing'), or a disinclination of global processing('central processing avoidance') [35].

Thus, a focus on details is one of the aspects of an autistic cognitive style. The fact that this preference for local processing is not (only) a voluntary choice, has been elaborated in the theory of enhanced functional processing [42], which states that autistic perception is locally oriented (visual and auditory) and has enhanced low-level discrimination. The 'involuntary' aspect seems to be the fact that switching from local to global is hard, for autists [55].

People within the autism spectrum are, for instance, less fooled by some visual illusions than neurotypicals, because of the strong local processing [24]. Here, we see that the autistic cognitive style is bottom-up, in contrast to the top-down thinking style that neurotypicals often use.

Explicit rules for categorization. This preference for local processing may be the reason behind the enhanced discrimination skills found in autism (discrimination is the ability to respond to differences in stimuli) [9]. Enhanced discrimination skills may form a hindrance for the task of categorization (the action or process of placing concepts or objects into classes or groups). Each individual object is perceived different from all other objects, which makes it difficult to create classes [56].

On the other hand, when taught a rule for categorization, autistic children are at least equally capable of categorization as other children [9]. Autistic cognitive style is thus characterized by strong discrimination skills, and by the need for (explicit) rules for categorization.

Autistic individuals have to *learn* categorical information because they miss the automatic mechanisms that allow neurotypicals to form prototypical representations of information spontaneously. Therefore, abilities that rely on the formation of prototypes, such as facial recognition, emotional expression, and the organization of information into different categories, are affected in autism. Individuals with autism must develop their own idiosyncratic strategies to perform categorical organization and discrimination tasks [69]. For instance, when asked to sort books, autistic individuals more often sort by color or size than neurotypicals [52]. The reason is that categorization of the contents of books is more difficult than categorization based on color.

For autistic individuals, it is difficult to discern which details are the most salient (for instance, those details that are socially important).

Context blindness. Another way of looking at the autistic cognitive style is to see it as context blindness [64]. Context blindness explains, for instance, why autistic people have such a hard time processing ambiguous information. Their brain does not use context to process information, which means that ambiguousness cannot be resolved by context. A preference for unambiguous language (logic, mathematics) is, therefore, also one of the aspects of an autistic cognitive style.

The positive side of context blindness, is that people within the autism spectrum make more consistent decisions: they are more likely than neurotypicals to represent the value of each attribute or option in isolation, rather than being influenced by the other items in a choice set. [17].

Rational reasoning. People within the autistic spectrum tend to prefer deliberate, rational reasoning ('system 1 thinking' [31]) to intuitive, fast reasoning ('system 2 thinking') , probably because their brain does not support intuitive reasoning as much as the brains of neurotypicals [8].

Weak generalization. The memory style of autistic individuals is a 'look-up table memory style', versus an 'interpolation' memory style in neurotypicals [49]. Autistic people use precise information, and will have difficulties with generalization, while neurotypical people learn by generalization. Generalization is the ability to reason inductively, to broaden something specific into something more general, by focusing on similarities.

Categorization (which we discussed before) is a form of generalization. Generalization is poorly developed in individuals with autism [48]. Also, there is a link with the focus on details, which prevents seeing what is the same between situations as opposed to what is different.

People in the autism spectrum tend to make decisions on the basis of (too) limited evidence (they tend to 'jump to conclusions') [30]. This is because autistic individuals try to understand the world by applying rules. Jumping to conclusions means that they presume rules based on too little information. In other words, with an autistic cognitive style, it is difficult to form abstractions (generalization as forming categories), and one tends to form rules, based on data, too soon (jumping to conclusions).

Systemizing. Austistic people show a high 'Systemizing quotient'. Systemizing is the drive to analyze systems or construct systems, to analyze the variables in a system, and to derive the underlying rules that govern the behavior of a system. Autistic people show a higher degree of systemizing than neurotypicals [4]. Systemizing differs from categorization and generalization: systemizing means that one forms structure bottom-up, from the details, analyzing data and constructing rules that explain the data (deductive resoning), while categorization and generalization means to form structure using a top-down approach (inductive reasoning).

Executive functioning. 'Executive functioning' is an umbrella term for those functions that are needed to reach a goal: planning, working memory, impulse control, inhibition, shifting attention, and the initiation and monitoring of action. In some of these areas, people within the autistic spectrum show impairments, in particular [26]:

- **Planning and organization** are difficult for people within the autistic spectrum. They have poor time management, and difficulties in prioritizing, coordination and sequencing of activities.
- **Mental flexibility** is impaired. Switching to a new train of thought, for instance, is a difficult task for people within the autistic spectrum. When task instructions do not contain an explicit indication of the rules to be applied, and do not explicitly state that a rule switch will occur, results show rather consistent cognitive flexibility deficits in autism [60]: it is difficult, when you are autistic, to detect that the rules have changed. Another aspect of mental flexibility is the ability to handle exceptions to a rule. People with an autistic cognitive style are good at conditional reasoning, but have problems with exceptions to a rule [47].

6 COGNITIVE STYLE AND SOFTWARE ENGINEERING

In this section, we discuss the thinking skills that are needed within software engineering, and compare them to the aspects of the autistic cognitive style that we reviewed in the previous section. The cognitive skills that we discern are: computational thinking, thinking 'like an engineer', and academic skills.

6.1 Computational thinking

Thinking like a computer scientist is coined as 'Computational thinking' by Jeanette Wing [70].

Computational thinking has a long and rich history [58], with, for instance, Dijkstra who stated that for algorithmic thinking, one should be able to transform informality into formality, that one should be able to form ones own formalisms and concepts, and that one should be able to go back and forth between various levels of abstraction [13]. Another example is Knuth, who stated that computational thinking involves representing reality, the reduction of a problem into simpler problems, abstract reasoning, information structures, attention to algorithms, managing complexity, and reasoning about causality [34].

Computational thinking is composed of at least three components [70]: algorithmic thinking, 'the thought processes involved in formulating problems so their solutions can be represented as computational steps and algorithms [1], abstraction (some see abstraction as the base of computing [36, 71]), and decomposition (the divide and conquer approach to problem solving).

Because a model to operationalize computational skills has been established [2], we compare these operationalizations with what we established about autistic thinking. This model discerns abstraction, generalization, algorithmic thinking, modularity, and decomposition.

Abstraction. Abstraction is operationalized by:

(1) *Separate the important from the redundant information*
(2) *Analyze and specify common behaviors or programming structures between different scripts*
(3) *Identify abstractions between different programming environments*

Separating the important from the redundant information is in direct conflict with the detail-focused cognitive style of autistic thinking. Separating important from redundant information is a form of categorization, and generalization. To be able to categorize, people with an autistic cognitive style need explicit rules.

Even when explicit rules have been given, it is a difficult task to recognize which information is redundant, when the superfluous information is described in various, slightly different, ways. In addition, context blindness plays a role: deciding which information is important, is only possible when one is aware of the context.

This aspect of abstraction plays a role in, for instance, problem analysis. It also plays a role in deciphering assignments, in understanding what the important aspects of an assignment are. Also, OO-modeling will probably be difficult without explicit guidance on how to capture a problem domain into a model.

Analyzing and specifying common behaviors or programming structures between different scripts is more concrete. People within the autism spectrum are more inclined to spot the differences than the commonalities. However, if explicit rules are given, this task will probably be doable for students with an autistic cognitive style. One may, for instance, show how to detect (almost) duplicate code, and how to create functions or methods to catch the commonalities.

Identifying abstractions between different programming environments (what is meant here, is to learn to work with various environments, such as Eclipse or IntelliJ), is, like the first aspect, in direct conflict with an autistic cognitive style, for the same reason. Discerning the details from the abstractions in programming environments demands categorization skills, that need explicit rules, for students with an autistic cognitive style.

It is probable that students with an autistic cognitive style will encounter more difficulties when asked to work with a new software tool or programming environment. In the words of a student:

> "For this assignment, I had to master too many new (for me) concepts: new environments (OS: Linux, IDE: Qt Creator), new language (C/C^{++}). The teacher spends (almost) no time on these new concepts, so I guess that this comes naturally for other students."

Summarizing, to teach abstraction to students with an autistic cognitive style, we need to pay additional attention. We may try to formulate rules to follow, to perform abstraction. These rules should be accompanied by exercises. Abstraction is a skill that cannot be taken for granted in the presence of an autistic cognitive style.

Generalization. Generalization (transferring a problem-solving process to a wide variety of problems) is operationalized by:

(1) *Expand an existing solution in a given problem to cover more possibilities/cases*

As we have seen, weak generalization is one of the characteristics of autistic thinking. One of the strategies of students with an autistic cognitive style is to systemize: to form structures 'bottom-up', and, doing so, find rules that might be used to generalize. Another strategy seems to be to 'jump to conclusions': to form rules from (too) few data.

Another view on generalization is that it is the ability to transfer a solution from one context to another. When it is clear what is context and what is the solution, this might not pose problems for students with autistic thinking, but the problem is, of course, that differentiating context from the essence is difficult. In most occasions, it is not made explicit what part of a case is context and which part is the essence, or even what the context of a problem is.

This means that, for instance, 'learning by example' will be difficult for students with an autistic cognitive style, unless it is made explicit what the essence of the example is. Also, because with an autistic cognitive style, one tends to jump to conclusions, examples may very easily put students on a wrong track.

In the words of a student:

> "Often, descriptions of assignments are unclear, but for me, it is even more difficult when there is no clear structure in the assignments. If I have to bridge a too wide gap between conceptual knowledge and practical knowledge, I get overwhelmed, and then I cannot think any more. If, on the contrary, we start with small assignments, each training one particular aspect, and later on, we combine these aspects in assignments, everything goes well."

Summarizing, generalization is difficult for students with an autistic cognitive style. As a remedy, teachers can try to be explicit about what constitutes context, and can explain explicitly which parts can be transferred into other contexts. Also, it is important to realize that 'learning by example' does not work for students with an autistic cognitive style. When giving examples, one has to spell out what the essence of each example is, and preferably give explicit rules or guidelines to follow.

Algorithm. Algorithm (writing step-by-step specific and explicit instructions for carrying out a process), operationalized by:

(1) *Explicitly state the algorithm steps*
(2) *Identify different effective algorithms for a given problem*
(3) *Find the most efficient algorithm*

Explicitly stating the algorithm steps suggests a procedural approach for algorithms. Creating algorithms in a procedural way combines well with a bottom-up thinking style and in particular with the preference for rational reasoning. To teach students how to follow a top-down approach, rules and guidelines are needed: the rules and guidelines from Felleisen [18] might help students with an autistic cognitive style to create algorithms with the end goal in mind, in a more top-down approach.

However, it is important how the problem that the algorithm should solve is formulated. Context that seems so obvious in the eyes of the teacher that it is left out, can form a hindrance for students with an autistic cognitive style.

If the problem is formulated with all context explicit, we see no conflicts with an autistic cognitive style with respect to identifying different effective algorithms for a given problem and finding the most efficient algorithm, in particular when given a clear definition of what is meant with 'efficient' (for instance, the fastest, the least code, and so forth).

Summarizing, bottom-up algorithmic thinking is probably one of the strengths within autism. Rules and guidelines for a more top-down way of working are a welcome help, and it is important to be explicit in the formulation of problems and exercises.

Modularity. Modularity (encapsulating elements such that they can be used independently), is operationalized by:

(1) *Develop autonomous code sections for use in the same or different problems*

In this case, context blindness is a double-edged sword.

On the one hand, context-blindness makes it easier to develop code that can be used in any context: developing autonomous code sections might be a strong point in students with an autistic cognitive style.

On the other hand, the same applies as in the case of algorithmic thinking: it is important how the problem that the code should solve is formulated. Also, context-blindness may lead to implicitly assuming a specific context, without realizing that. Specifying explicit pre- and postconditions can help.

In the words of our students:

> "What do you mean with 'making a selection'? Do you mean a choice (= selection)? Or do you mean a set (= selection). Dutch ! = Java. The question has more than one meaning.
>
> 'A selection of columns' can mean, at the level of the user, that a specific column should be chosen to be read, but also, that the program should use a specific set of columns. This is because 'selection' can both point to the process of choosing, as to the choice itself."

Summarizing, the context and formulation of the problem should be very clear. It is advisable to ask to explicitly specify pre- and postconditions.

Decomposition. Decomposition (breaking down problems into smaller parts that may be more easily solved), operationalized by:

(1) *Break down a problem into smaller/simpler parts that are easier to manage*

Here, the problem of discerning the essence from additional context may also form a problem. The lack of central coherence and problems with executive functioning (planning and organization) may for a hindrance with respect to decomposition. In order to decompose a problem into smaller steps, one should be able to see the problem as a whole in the first place (instead of as a sum of details), and one should be able to discern the essence from less important details.

Decomposition is, in essence, a form of top-down thinking, and we have seen that the strength in autistic thinking is bottom-up. Decomposition can also be seen as part of executive functioning (it has to do with planning and organization). As we have seen, there are impairments here.

Summarizing, for the skill of decomposition, there are several hindrances for students with an autistic cognitive style. As in the case of abstraction, these students probably need more explanation and more exercises to master this skill.

6.2 Thinking as an engineer

Engineers seek optimal solutions to problems. Engineers should be able to explain why a particular solution to a problem is best [51].

Frank [20] discerns three categories in engineering: *aims* (engineering design is directed toward the creation of new technological components), *knowledge, processes and tools* (which means that a knowledge base should be created, models and laws should be applicated, heuristics should be used), and *thinking*. In thinking, he discerns:

Synthesis. If synthesis is defined as 'an aspiration to understand how' (as Frank does), an autistic thinking mind will not have difficulties with this skill. If, on the contrary, it is defined as the skill to create a whole from parts, we may expect a need for additional rules of thumb, and exercises.

Concrete thinking. The preference for local processing, for thinking in details, and the weak generalization, means that concrete thinking is a strong point in an autistic cognitive style. Concrete thinking is the default thinking style for students with an autistic cognitive style.

Systems thinking. Systems thinking can be translated as looking at the whole instead of at the parts. As we have seen, seeing the whole is a difficult task for someone with an autistic cognitive style. Students with this thinking style will require rules of thumb, and exercises, to learn to see the whole, and to pay respect to the whole.

Advance toward the desirable. When thinking about how to reach the goal, it must be clear what the goal is in the first place. It is important to make the goal explicit, for students with an autistic style of thinking.

As we have seen, executive functioning applies to what is needed to reach a goal. Executive functioning is weak in autistic people. To determine how to reach the desirable, rules of thumb will be needed: explicit guidelines.

Optimal solution. What is optimal should be made clear, or students should be taught how to define optimal themselves. If that is clear, thinking about what is optimal can be done by rational reasoning, which is a strong point.

6.3 Academic thinking

Academic thinking comprises, at least, critical thinking and higher-order thinking.

Critical thinking. (being able to make an evaluation or judgment [39]) Critical thinking skills have been formulated as follows [16]:

Interpretation (to comprehend and express the meaning or significance of a wide variety of experiences, situations, data, events, judgments, conventions, beliefs, rules, procedures, or criteria)
As we have seen, interpretation is difficult for students with an autistic cognitive style, unless the context has been made clear.
On the other hand, context-blindness also has an advantage with respect to interpretation: students with an autistic cognitive style will not automatically assume a context, and may, therefore, see different interpretations, that are equally valid. Forming rules as a string point will also help with interpretation.

Analysis (to identify the intended and actual inferential relationships among statements, questions, concepts, descriptions, or other forms of representation intended to express belief, judgment, experiences, reasons, information, or opinions)
Context blindness can both be a hindrance (when context is held implicit) and an advantage (when assuming a context hinders others to see alternative ways for analysis). On the other hand, the focus on rules, and the ability to form rules, is a strong point when analyzing a text. The rational reasoning aspect of the analysis process is a strong point as well.
A bottom-up thinking style may lead to a different analysis than a top-down thinking style. With respect to analysis, one can therefore see diversity in thinking style as positive. reasoning will be more deductive than inductive.
Analysis can be thought of as a form of systemizing: finding the rules, the patterns, in a given situation, and applying them. As we have seen, systemizing is a strong point in autistic thinking.

Inference (to identify and secure elements needed to draw reasonable conclusions; to form conjectures and hypotheses; to consider relevant information and to reduce the consequences flowing from data, statements, principles, evidence, judgments, beliefs, opinions, concepts, descriptions, questions, or other forms of representation)
Weak generalization may be a hindrance in the inference process; rational reasoning is a strong point.

Evaluation (to assess the credibility of statements or other representations that are accounts or descriptions of a person's perception, experience, situation, judgment, belief, or opinion; and to assess the logical strength of the actual or intended inferential relationships among statements, descriptions, questions, or other forms of representation)
Assessing the logical strength of relationships among statements etc. will be a strong point, in an autistic cognitive style.
With respect to assessing the credibility of perceptions, experiences, and so forth, students with an autistic cognitive style will use the same rational reasoning, without respect for context. This may be both a hindrance and an advantage.

Explanation (to state and to justify that reasoning in terms of the evidential, conceptual, methodological, criteriological, and contextual considerations upon which one's results were based; and to present one's reasoning in the form of cogent arguments)
For students with an autistic cognitive style, we see no problems.

Self regulation (self-consciously to monitor one's cognitive activities, the elements used in those activities, and the results educed, particularly by applying skills in analysis, and evaluation to one's own inferential judgments with a view toward questioning, confirming, validating, or correcting either one's reasoning or one's results)
The lesser mental flexibility in autism might lead to a more rigid thinking style, that might form a hindrance with respect to self-regulation.

Higher-order thinking. Occurs when a person takes new information and information stored in memory and interrelates and/or rearranges and extends this information to achieve a purpose or find possible answers in perplexing situations [39].

Because of the 'look-up table memory style', this may be one of the strong points of students with an autistic cognitive style. However, because the answers are often found using a 'different', bottom-up thinking style, the answers may sometimes be unconventional in the eyes of others.

When abstraction and generalization are needed, we refer to what we concluded about those skills.

6.3.1 Academic writing. Most students struggle with academic writing. It is, therefore, interesting to check whether some aspects of academic writing are especially hard for students with an autistic cognitive style.

Teachers often fail to explicitly describe what good academic writing style comprises[38].

Academic writing demands skills at various levels:

- Selecting/evaluating information sources: finding information in library and internet, and understanding which information is relevant;
- Synthesizing the ideas/arguments from other sources with one's own ideas/arguments;
- Referencing: conventions of citation, avoiding plagiarism, knowing why, when and whom to reference, understanding referencing as a method of a. providing evidence, acknowledging the work of others in the field, giving greater authority to one's own ideas, constructing knowledge;
- Writing ideas/arguments up into a structured,coherent text: structuring, language skills (spelling, grammar, rhetorical strategies, cohesion), using appropriate terminology, style, conventions, participating in specialist discourse, understanding rhetorical processes needed for the construction of knowledge [73].

All these skills should be explicitly taught to students. For students with an autistic cognitive style, we see several skills that will be especially difficult:

Understanding which information is relevant All students should be taught how to find relevant articles (for instance, by starting to glance over abstracts), but this is especially true for students with an autistic cognitive style: thinking in details is a hindrance when searching for relevant articles, and finding thousands of possibilities.

Making meaning with unfamiliar discourse Again, this is difficult for all students, but with an autistic cognitive style, context blindness might pose an additional problem. Students should be taught explicitly that concepts may have a (slightly) different meaning in another context, and they should be taught how to recognize the context in which a concept is used. Of course, this should be accompanied by exercises.

Structuring Structuring an academic text is partly a matter of convention, that can (and should) be taught explicitly. Partly, it depends on what is the most important part of a section, a paragraph, or a sentence, and to base the structure on that (following rules that can be taught).
As we have seen, deciding what is important is difficult with an autistic cognitive style: this should be taught, accompanied by exercises to train this skill.

7 GUIDELINES

Now, we are able to formulate a first set of guidelines for inclusive education for students within the autism spectrum, with respect to cognitive style, based on what we found in literature about autistic cognitive style and the thinking style in software engineering. These guidelines have been confirmed by anecdotic evidence from autistic students telling us about the problems they encounter, but we would like to gather more data.

Explicit Context. In general, texts should be formulated in such a way that one needs as little context as possible to understand what is meant. An autistic thinking style means that texts are read 'as is', and are processed as though there is no context. That means that texts will be difficult to follow when it is assumed that the reader will automatically fill in which context is presumed.

To make context explicit seems simpler than it is: one omits context because the context is presumed unconsciously. As a teacher, one has to put oneself in the shoes of someone who will read the text, with only the text as guideline for what it means, and nothing else.

Especially in the case of assignments and exams, it should be made very clear what one expects from a student.

On the other hand, teachers should supply guidance in teaching students how to read material without explicit context. There should be support, for instance, for how to find the implicit context in an academic source, for how to interpret a scientific article.

Explicit guidelines. In many areas, one should give explicit guidelines.

For instance, one cannot expect that everyone is able to 'learn by example'. One should point out what the salient aspects of the example are, and which general rules one may deduce from an example. Otherwise, one can expect that some students may have drawn very different conclusions, and will stick to those conclusions.

In particular where the approach is top-down (for instance, in problem analyzing and design based on such analysis), one should give explicit guidelines on how to do that. Also, one might try to find other ways to solve problems, that require a more bottom-up approach. Both top-down and bottom-up approaches may lead to good solutions.

Teachers should be aware of the fact that students with an autistic thinking style may come up with different solutions than the teacher might expect, because of their bottom-up thinking style.

Explicit guidelines are also needed where finding relevant aspects are important. For instance, one should explain how to proceed when trying to find relevant literature.

Students should also be given explicit guidelines with respect to structure texts.

With respect to 'thinking as an engineer, students with an autistic thinking style will probably show strengths. However, they will need rules and guidelines on how to pay respect to the whole system, as opposed to only parts of the system.

Exercises. When explicit guidelines are given on how to perform a task, these should be accompanied by exercises.

Consequences for education. These points have consequences in many areas. For instance, one may not take it for granted that students with an autistic thinking style will pick up what is relevant from listening to a talk. Handing out handouts with the salient points beforehand might help.

Course material should be revised. In places where examples are used to teach something, one should make explicit what the students should learn from these examples.

For many tasks, we should develop explicit guidelines. Sometimes, these guidelines may be very precise. At other times, they may state that there are no strict rules, and explain a general approach to tackle a problem.

In the very first place, teachers should be taught about autism and the autistic cognitive style, so they can see their course material and their lessons from the perspective of autistic students.

8 DISCUSSION

We formulated guidelines for inclusive education in software engineering, based on what is known about the autistic cognitive style and on the cognitive aspects of software engineering. As such, our exercise is not purely speculative, but do not have empirical evidence other then the anecdotical evidence that students sent us.

We think our effort is worthwhile nonetheless, for a couple of reasons.

First, It is very difficult to find conclusive information about hindrances in education for students within the autistic spectrum, for several reasons. In the first place, one faces the same difficulties as in estimating the number of students within the spectrum: not every student is willing to disclose his or her diagnosis, and not all students who are within the spectrum know that. Also, it is difficult to point out hindrances you have, when you think that all fellow-students will probably face the same hindrances. To be able to point out what is a hindrance, a student would have to know how non-autistic students think, how the neurotypical cognitive style is.

Second, although Software engineering has a relatively high percentage of students within the autistic spectrum, what autism is and what the autistic cognitive style is, does not belong to the general knowledge of most lecturers. An overview of cognitive characteristics is therefore worthwhile in itself.

Third, giving explicit guidelines on how to proceed with a (complex) task, is part of the 4C/ID approach (the four component to instructional design model) to teaching complex tasks [41, 61]. It is interesting to see that many of the recommendations we give overlap with this preferred approach to teach complex tasks. It seems, therefore, that making out education more inclusive with respect to autistic students, will result in better education as a whole. Students within the autistic spectrum might be seen, so to speak, as canaries in the coal mine with respect to suboptimal education. Focusing on what such student need may be a good starting point to improve education.

9 CONCLUSIONS AND FUTURE WORK

Based on literature and on the knowledge of an expert, we formulated the autistic cognitive style. We compared these characteristics with the cognitive skills that are needed within Software engineeing. Based on that comparison, we predict possible hindrances. We formulated guidelines that might help to take away these hindrances.

Finding out how to support an autistic cognitive style is a new research area. Therefore, there are many ways in which we would like to extend this work, for instance:

Ask autistic students We want to ask autistic students about the difficulties they experience through questionnaires, and we will organize meetings with autistic students, to brainstorm about how education can be improved for them.

Coaching thesis writing Probably, writing a thesis is the most difficult part of the study for almost any student; for autistic students, this is especially true. We would like to investigate good practices in coaching autistic student while they write their thesis. This can be done by interviewing students, interviewing teachers, and by developing and trying out an approach.

Screening a course It would be worthwhile to develop a set of guidelines for education that can be used to screen a course on 'inclusiveness' with respect to autism. We would have to validate the guidelines in several ways: check whether they are concrete enough to use when reviewing a course and check whether the guidelines really help autistic students. We could interview both students and teachers to find out more about the problems they encounter.

Collaboration To support collaboration between students, both autistic and neurotypical, we would like to develop guidelines for collaboration that recognize different cognitive styles.

Explicit guidelines One of our goals is to develop explicit guidelines for processes that are inherently nondeterministic. Examples are, for instance, domain analysis or use case modeling. We would like to check whether explicit guidelines really help autistic students.

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