Inquiry in University Mathematics Teaching and Learning: The PLATINUM Project
Corresponding author: Lukáš Másilko, masilko@teiresias.muni.cz
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CHAPTER 4

Students With Identified Needs and IBME

Lukáš Másilko, Clare Trott

4.1. Introduction

In this chapter we will focus on students with identified needs and try to analyse the differences they may display when participating in inquiry-based mathematics education. Students in universities are diverse by their characteristics and it is difficult to comply with all their needs individually and on demand. Therefore, we will follow the social model of disability and its main idea emphasising the responsibility of educational institutions as the key factor in creating an inclusive learning environment (see Section 4.2). According to our own perspective as explained in Section 4.3 it is much easier to be prepared in advance to try to satisfy all the possible students' needs, preferences and requirements. In Section 4.6, we will introduce readers to the principles of *Universal Design*, a methodology to follow if one wants to create an inclusive learning environment that reaches the needs of as many learners as possible. "However, it is necessary to know the specific needs of each student, and therefore the categorisation of the needs should rather help to find appropriate support, methods, forms and tools in the learning process" (Čerešňová, 2018, p. 16). Such typology of students with identified needs will be introduced in Section 4.4 and followed by a detailed study of students' differences when they undertake an inquiry within university mathematics courses (Section 4.5).

4.2. Diversity of Students' Characteristics and Needs

It is difficult to comprise the meaning of special (educational) needs in a few sentences. We find a definition of special needs in the Cambridge dictionary[1] as "the particular things needed by or provided to help people who have an illness or condition that makes it difficult for them to do the things that other people do." Another, very similar explanation is offered by the United Nations in the Convention on the Rights of Persons with Disabilities (Article 1): "Persons with disabilities include those who have long-term physical, mental, intellectual or sensory impairments which in interaction with various barriers may hinder their full and effective participation in society on an equal basis with others" Unites Nations (2006). Many definitions focused on educational aims and delivery are based on the same medical model: special educational needs are caused by an individual's health state and affect his/her ability to learn. "In many countries ... students are required to be formally diagnosed and identified, and adjustments are made so that they can fit in to existing approaches to learning and teaching" (Pollak, 2009, p. 270).

On the other hand, based on our experience, there are a lot of students who choose not to disclose their learning differences, behavioural problems, mental health issues,

[1] https://dictionary.cambridge.org/dictionary/english/special-needs

physical disabilities etc. They try to cope with their studies without any special help. Furthermore, a need for help can arise from different circumstances than long-term health conditions and difficulties mentioned above and described in more detail in Section 4.5. For example, students may need to study a course remotely as they were accepted for a study placement or traineeship in a company. Or they are not able to study for some time as they need to deal with the death of a family member. We can add further characteristics such as different learning and cognitive styles or language difficulties of non-native speakers and continue with other examples. Should we consider these needs as special too?

It is clear every student is diverse by his/her characteristics and needs and it is very difficult to address this heterogeneity individually, one by one. Flexibility in all the teaching and learning activities is the key idea to provide this group of diverse people with an opportunity to achieve desired goals.

Taking this diversity into account, we prefer to use the social model of disability whereby difficulties are seen as a product of social circumstance, removing the onus from the individual and giving the responsibility for inclusive learning environments to educational institutions. "This is in contrast to the medical model of disability that concentrates on the impairment as the cause of the disability" (Drew, 2016, p. 30).

According to the social model there are two key terms with a different meaning:

- impairment (biological limitations in a person's functioning) and
- disability (limitations in access and inclusion caused by barriers educational institutions produce).

The social model requires that educational institutions take on responsibility and break down barriers in order to ensure an inclusive learning environment. And based on our experience, individual's disability is in many cases caused by society's response to his/her impairment. With respect to our preference, from now on we will use the term 'identified needs' instead of 'special needs' as we consider all the students' differences in respect of their health condition and/or their learning preferences as nothing 'special' anymore.

4.3. PLATINUM Partners' Perspectives

Partners of the Platinum project come from seven different European countries and many of them experience teaching students with identified needs. During the first year of the project they were asked to describe the communication between teachers, students with identified needs and offices for their support in the partners' universities. In most cases, teachers receive information on students with identified needs regarding their functional specificities and reasonable adjustments that should be offered in order to meet these specificities implied by their learning differences, behavioural problems, mental health issues, physical disabilities etc. Such information is given by the office for students with identified needs and

(1) has to be approved and confirmed by students, including its wording shared with teachers;
(2) may be reduced (at some universities teachers receive only a list of students and specification of extra time for them during written tests);
(3) is offered at the beginning of the semester or before the period of assessment, and occasionally during the semester if it is a new student or his health condition changed rapidly. Some information can be given during semester if the student is newly identified.

Confidentiality plays a part here and it must be agreed what information is shared and with whom.

Teachers develop their courses well in advance, usually not at the beginning of the semester it is delivered to students. When planning the course's curriculum, designing study materials and teaching units, or deciding on methods of assessment, teachers often do not have any information about students and their differences or needs. In many countries, adjustments for students with identified needs are made 'on demand' and with the intention to fit into existing approaches to learning and teaching because the course's design has already been finalised. "This process is better than leaving them to 'sink or swim', but the assumption is that the procedures of higher education are immutable" (Pollak, 2009, p. 270). Taking the diversity of students into account when designing the very processes of learning, assessment, and organisation, is a much more inclusive way and may result in benefits for all learners.

4.4. Typology of Students With Identified Needs

Although we constitute this chapter on the principles of the social model of disability, the perspective of the medical model is taken as an input aspect to describe groups of students whose ability to learn is affected by their health condition or specific learning difference. Because this book is focused on education which could be understood as a continuous interaction between teachers and students, the following categorisation of students with identified needs is proposed based on functional principles with the emphasis on working and communication procedures. The categories are: students with

(1) specific learning differences, for example Dyslexia, Attention Deficit (Hyperactivity) Disorder—AD(H)D, Dyscalculia, Dyspraxia;
(2) Autism spectrum disorder including Asperger Syndrome;
(3) mental health issues, mostly represented by anxiety, depression and low resistance to stress;
(4) physical/mobility disabilities, for example those using a wheelchair and/or crutches (lower limbs impairment), or with disturbed fine motor skills (upper limbs impairment);
(5) visual impairment;
(6) hearing impairment;
(7) disturbed communication skills; and
(8) other chronic conditions, for example diabetes, epilepsy, multiple sclerosis, etc.

When preparing the categorisation we draw on three different typologies originating from the US (Lee, n.d.), United Kingdom (UK Department for Education & Department of Health, 2014), and Czech Republic (MŠMT ČR, 2018). We believe these eight groups of students differ in needs when studying at university. However, it is important to say, many individuals can fit into more than one category with their primary health condition since this can affect their abilities in different ways. As an example, we could consider a student with multiple sclerosis included in the last category. "The initial symptom of Multiple Sclerosis is often blurred or double vision, red-green colour distortion, or even blindness in one eye. Most MS patients experience muscle weakness in their extremities and difficulty with coordination and balance" (NINDS, 2018). These indicators affecting individual's vision and mobility may convince us to include students with multiple sclerosis in the 4th or 5th category. This example can also help us to understand the necessity to identify the full range of an individual's needs, not

only those resulting from the primary health condition or specific learning difference. As we described above, the proposed categorisation is based on functional principles and therefore does not include some of the categories you may feel are missing, for example Cerebral Palsy. We didn't create more groups as we assumed students with Cerebral Palsy are mostly affected in their physical abilities and hence belong to the 4th category.

4.5. Inquiry-Based Instruction and Students With Identified Needs

In this section we look at pedagogical processes during inquiry-based instruction. Firstly, we identify which processes a teacher should pay attention to with regard to student differences. Secondly we discuss what this means for specific learning differences of students when they are engaged in inquiry.

4.5.1. Pedagogical Processes During Inquiry-Based Instruction. In the following, we try to look at the pedagogical processes that are present during inquiry-based instruction and how students with identified needs can take an active part with regard to their learning and working, communication, attention, behavioural and emotional, sensory or physical and other differences. Although we have just introduced the categorisation of students with identified needs based on the medical model with regard to functional principles, we try to investigate differences in their engagement to inquiry-based activities according to the social model of disability. Different ways of engagement should be respected and it is the responsibility of teachers to include actively all the learners into educational activities during instruction.

"Inquiry is about asking questions and seeking answers, recognising problems and seeking solutions, exploring and investigating to find out more about what we do that can help us do it better" (Goodchild et al., 2013, p. 396). During inquiry-based activities, students interact in small groups or together with teachers, examine textbooks and other sources of information to see what is already known, use tools to gather, analyse, and interpret data, make observations, propose explanations and predictions and communicate results of their work (Artigue & Blomhøj, 2013). When starting an inquiry-based activity a teacher may announce goals and questions to answer, s/he can also advice on methods and tools to start with in order to get to the 'end' of inquiry, s/he can help with interpretation of results.

Even though it is a student who conducts his/her learning, there are several pedagogical processes a teacher should pay attention to with regard to student differences. Let's identify the processes chronologically by breaking down an inquiry activity into some typical sub-activities:

(1) Start of the inquiry-based activity including instructions given by teachers;
(2) Students' collaborative work in small groups with plenty of discussions, communicating observations, conjectures, uncertainties etc.;
(3) Using tools and software applications to gather, analyse, and interpret data;
(4) Presentation of results;
(5) Final discussion leading to an answer to the questions given or formulated in the beginning of the activity;
(6) Summary of the activity.

In the remainder of this section, we try to capture student differences when they undertake any of the previous processes according to the categories of students with identified needs described above. In Section 4.6 we will try to give advice on how to deal with such student differences.

4.5.2. Students With Specific Learning Differences. Specific learning differences are neurodevelopmental in nature and affect individual's verbal and/or visual abilities. Research shows people with specific learning differences process information in the brain differently and use contextual understanding to the maximum possible extent without attention to details. Such students may display differences in performing everyday tasks such as learning and remembering, information perception, time management, attention span (Pollak, 2009; Barnová et al., 2020).

The most common specific learning differences are listed below.

- *Dyslexia* (sometimes called Reading Disorder) displays in many areas such as reading skills (slower pace of reading, errors in reading, reading comprehension), spelling and writing.[2]
- *Dyspraxia* (sometimes called Developmental Coordination Disorder) affects organisation of movements and body coordination as brain messages are not being properly or fully transmitted.
- *Dyscalculia* can be understood as weaker mathematical abilities displaying in problems with number manipulations and understanding number concepts and relationships, performing mathematical calculations and mathematical conceptualisation.
- *Attention Deficit (Hyperactivity) Disorder*, in short AD(H)D, is indicated by problems with concentration, lower resistance to distraction, deficits in behavioural inhibition and poor regulation of one's activity within the demands of a situation.
- *Auditory Processing Disorder* (APD) manifests itself in problems with processing information one can hear; it is difficult for his/her to recognise and interpret sounds.

In many cases, these specific learning differences come together and may result in mental health issues (anxiety or depression) and isolation.

If we think about pedagogical processes during inquiry, we should pay attention to the opening phase when a teacher introduces participants to a problem and gives instructions. When following the specification of the inquiry-based activity in written form, students with specific learning differences may read text at a slower pace, experience difficulties with the surrounding text or understanding the content (dyslexia) and can be distracted both by internal and external stimuli (ADHD). On the other hand, listening to spoken instructions may also be difficult for them as they are easily distracted by background noise or sudden, loud noises, and having to simultaneously listen and write down notes, recalling details being heard. In order to be focused on the problem students need to understand the purpose of the inquiry.

During the inquiry, students with specific learning differences may have problems with organising their activities. It is difficult for them to read the words in which the problem is embedded, so particularly wordy problems and tasks in which mathematical notation is mixed with text. They also struggle with writing solutions in logical order and aligning mathematical statements. Memory, in particular, is an issue such as remembering formulae, theorems and mathematical terms that are not firmly cemented yet. Students focus on contextual understanding of the problem and therefore are considered to be good problem-solvers with creative and original ideas although writing down their solutions can be problematic with little mathematical flow. If highly motivated by the problem, they are very determined and don't give

[2]In some countries, difficulty in writing is known as Dysgraphia and is caused by lower fine motor skills and lower visual motor coordination.

up. Students, especially those with auditory processing disorder and ADHD, may have problems in following a conversation when listening to more than one speaker or hearing lots of background noise. If participants of inquiry are supposed to use tools or software applications they are not familiar with, it could be difficult for them to manipulate/use these effectively (dyslexia, dyspraxia).

When presenting inquiry results, students with weaker reading/writing skills prefer to describe their findings verbally or diagrammatically. Because of problems with recalling the details of what they heard during the final discussion and difficulties in simultaneously listening and writing, students may forget to make notes about important facts they learnt from others. They may get behind in note taking or need a slower pace. All the students, not only those with specific learning differences, need to know they can make mistakes and come up with incorrect or incomplete answers and comments so they are not afraid to offer their opinion. It is the responsibility of a teacher to conduct the conversation and motivate all the students to share their ideas.

4.5.3. Students With Autism Spectrum Disorder Including Asperger Syndrome. Autism spectrum disorders (including Autism and Asperger syndrome) are neurodevelopmental in nature and affect the 'triad of autistic impairments': communication, social interaction and flexible thinking (i.e., ability to adapt to new situations). These three abilities are limited most frequently, however autism spectrum disorders can display some (not necessarily all) of the following indicators (Burgstahler & Russo-Gleicher, 2015; Pollak, 2009):

- problems with concentration and hyper-focus;
- issues with time management, planning activities, self-organisation;
- differences in adapting to unexpected situations (preference of classroom activities which are predictable/routine, lower ability to react intuitively);
- ineffective participation in conversations (asking too many questions, making comments not related to the topic of discussion, poor nonverbal communication including lack of eye contact, facial expression, and body postures and gestures to regulate social interaction);
- hyper-sensitivity (they can be easily distracted by visual or auditory stimuli or by touch);
- misunderstanding particular forms of language (e.g., sarcasm, jokes, irony, metaphors, humour, abstract concepts).

Students with autism spectrum disorder need to receive structured and accurate instructions, as clearly as possible, in order to focus their activities to the task and not spend too much time trying to understand the meaning of what was written/spoken. It is difficult for them to 'read between the lines,' to understand things not being said explicitly, to make intuitive decisions during the work. To avoid unexpected situations as much as possible, they prefer to have an opportunity to prepare for the session and get to know in advance what will be discussed, which tools/applications they are supposed to use, and so on.

Working in small teams and interacting with other members of the group could be a challenging activity for students with autism spectrum disorder. They need more time to reply as they have to be fully concentrated to understand what is discussed. They may interrupt the discussion by an off-topic question or may be afraid to pose questions at all because of negative reactions from other members of the group. It is difficult for them to lead other members of the team or to anticipate their role and responsibilities. Careful management of the group is needed. On the other hand, if they work independently they are likely to lose track of time and focus on researching

details that are not very important for finishing their inquiry. Despite these differences in communication, students with autism spectrum disorder may come with valuable contributions especially when they find the topic of inquiry interesting or even fascinating. In such a case they deeply immerse themselves in research and achieve noticeable outcomes. They can prove to be excellent mathematicians.

When presenting their results or participating in the final discussions, students with autism spectrum disorder need more time to formulate their thoughts as they carefully choose each word to express accurately what they have in mind. They have difficulties in identifying the appropriate moment to enter or link to an existing discussion and sometimes need to be clearly invited to offer their opinion and comments. On the other hand, they can sometimes talk too much as they become 'experts' on the subject in question or they are overloaded by expressing their thoughts and do not have capacity to control their performance. In order to let others speak they need to be tactfully advised to finish so they don't lose motivation to express themselves on another occasion.

4.5.4. Students With Mental Health Issues. "Mental health problems range from the worries we all experience as part of everyday life to serious long-term conditions" (Mental Health Foundation, n.d.). The most common emotional issues students in higher education can experience are stress, anxiety and depression. "More serious and less common mental health difficulties include conditions such as schizophrenia and bipolar disorder, but students with these conditions are likely to arrive at university with their conditions under control" (Pollak, 2009, p. 201). People under medical treatment may take prescribed medication and/or attend one-to-one regular sessions with mental health support staff such as therapists, clinical psychologists, psychiatrists, social workers, etc. Despite that, many students try to keep their feelings hidden and deal with their emotional problems alone without any special support as they may be afraid of other people's reactions. The most common characteristics students with mental health issues display are

- lack of energy, weariness and inhibition (may be caused by medicine, insomnia, anxiety, etc. and may affect regular daily routines);
- withdrawing into oneself, inconstant motivation to work, low self-confidence;
- weakening of cognitive functions (concentration, working memory, information processing and sorting, pace of thinking, etc.); and
- low resistance to stress, restlessness and intrusive thoughts that distract from the immediate task.

"Although certain symptoms are common in specific mental health problems, no two people behave in exactly the same way when they are unwell" (Mental Health Foundation, n.d.).

Students with mental health issues need to feel they are safe and in control of the situation in order to avoid stressful moments, make rational decisions and stay focused. It is very helpful to provide them with clear and widely available information about the availability of resources, to indicate a time schedule of inquiry and to discuss the possible flow of activities leading to achieving desired goals. In such a case they can start the inquiry more easily as they can anticipate what is going on and may organise their activities in a better way. The process of forming groups can be challenging for students with mental health issues as they may be afraid of another member's reaction to their participation in the group.

"Assessed group work can also present difficulties for students who feel that they cope best when they can work on their own at their own pace" (Pollak, 2009, p. 205).

They may feel bounded by the fact that other members of their team rely on results of their work. On the other hand, being a member of a group may compensate for an individual's weaker abilities to organise the process of inquiry. Sharing the workload with others may relieve the pressure and enable students with mental health issues to focus on activities they feel confident in performing. Weaker cognitive functions can display in differences with generalisation and transfer of knowledge to problems experienced for the first time. Students with mental health issues often perform better in specific 'routine' tasks as they are not so overloaded by thoughts of failure and other doubts (Abels, 2014). For the same reason, they need to verify their inquiry is in the right direction. Dr. Vicky Klima (n.d.) from Appalachian State University pointed out another problem many students face: "Oftentimes when people read a problem and they don't know how to do it, they just skip it." In such a moment, students with mental health issues may tend to slow down/stop their work as they are not focused and are overwhelmed by thoughts of failure.

"Most students with mental health issues will have no difficulty with the research and reading that goes into preparing for presentations and seminar discussion, but the performance anxiety that is present for most people in public speaking can present huge difficulties for them" (Pollak, 2009, p. 205). They are worried by other students' reactions and teachers' critical comments in case they come up with incorrect or incomplete answers or remarks. Despite these concerns they need to receive feedback as soon as possible in order to control the situation and avoid uncertainty. Generally, if they need to wait a long time for any kind of support (assessment of their work, answers to their questions, etc.), they tend to occupy themselves with concerns and may start to feel anxious about that.

Mathematics anxiety can be viewed as a serious issue that sits alongside more generic anxiety. It can be defined as: "Feelings of tension, apprehension, or even dread that interferes with the ordinary manipulation of number and the solving of mathematical problems" (Ashcraft & Faust, 1994). Mathematics anxiety can be characterised in three ways:

- physiological (nausea or increased heart rate),
- psychological (confusion or mind chaos), and
- biological (preoccupation with worry or reduced working memory).

Students with mathematics anxiety will not be able to study effectively and may avoid their studies entirely.

4.5.5. Students With Physical/Mobility Disabilities. A physical disability is defined as a limitation on a person's physical functioning, mobility, dexterity or stamina. We can distinguish two major types of physical disabilities:

- Musculoskeletal Disability is caused by muscular or body deformities, diseases or degeneration (loss or deformity of limbs, muscular dystrophy, brittle bone disease);
- Neuro Musculo Disability is defined as an inability to perform controlled movements of affected body parts due to diseases, degeneration or disorder of the nervous system (Cerebral Palsy, Spinal cord injury, Spina bifida, etc.).

If lower limbs are affected, a person's mobility is limited as well as the body coordination and balance. Such people may use wheelchairs to enhance their mobility or walk with the aid of callipers, crutches or walking stick. In the case of upper limbs impairment, individual's fine motor skill can be disturbed and such a student may display differences in writing (taking notes by hand or on keyboard) and manipulating physical objects and equipment (for example printed material and stationery). Cerebral

Palsy may also affect people's speech and vision as well as their ability to concentrate and other cognitive functions. "Some students may experience chronic fatigue and for others there will be extreme fluctuations of energy from day to day" (ADCET, n.d.).

Some students may experience reading/writing differences when working with a print version of instructions—an inability to write using a pen, involuntary head movements which affect the ability to read standard-sized print, reduced ability to manipulate books and other printed material, etc. (ADCET, n.d.). They may prefer, especially those with upper limbs impairment, the digital editable version of instructions in order to write their notes and computations on a computer-based device equipped with supportive tools such as adapted mouse and keyboard, or system for eye tracking and typing. As they may display differences in writing pace due to reduced fine motor skills, the opportunity to make/access an audio or video recording of a lesson is beneficial for them (they may complete their notes later in case they did not manage that during the instruction).

Students may display differences in using software applications to gather, analyse and interpret data and manipulating physical objects or instruments in laboratories. Together with experts in assistive technology[3] they may search for more effective ways to use the applications (for example to access parts of the program more quickly or to set the program interface to be more user-friendly for those using adapted input tools). Limitations in the use of hands (their shaking, damage of finger motor capacities) or difficulties of access for students using wheelchairs and other walking aids may radically affect their possibilities to manipulate instruments in laboratories or to work with standard ICT available in classrooms (Čerešňová, 2018). In general, any non-standard arrangement of furniture and other equipment in the classroom may cause an accessibility issue for students with physical/mobility disabilities.

When working in groups, presenting results of an inquiry or discussing, students mostly do not display any differences.[4] "They may have frequent or unexpected absences from class owing to hospitalisation or changes in their rehabilitation or treatment procedure. When there is limited time to move between venues, students may miss the beginning of a class" (ADCET, n.d.).

4.5.6. Students With Visual Impairment. People with visual impairment have decreased ability to see to such a degree that it cannot be corrected by usual means (e.g., glasses or contact lenses). "The impairment may be the result of a range of conditions and its impact will depend on the type, extent and timing of vision loss" (ADCET, n.d.). There exist a lot of different visual impairment categorisation models but we take the most simple one regarding the possibility of using sight or not.

- Partially sighted students can use the sight to read but need to modify the visual display of information or adapt conditions for reading. In the case of electronic documents, the modification is based on zooming in/out and other optical changes such as colour layout and setting the display of important system or application elements[5] to be more visible. They may also display differences in working with a printed version of a study material/written

[3]Assistive technology is a tool, software or equipment that helps people with identified needs to learn, communicate or generally to perform activities of daily living (e.g., a wheelchair, an application that reads text aloud, a magnifying glass, etc.).

[4]Individual's communication and speech skills can be affected due to Cerebral Palsy or traumatic brain injury, but we will discuss such a difference in the next part of this chapter.

[5]Partially sighted users of software magnifiers can change the size, colour and border of mouse cursor and can ask for highlighting of the line which is actually spoken by synthetic human voice. This feature is also available to users of some software magnifiers such as ZoomText or Magic.

test. Generally, they need to receive enlarged print and set up to their reading preferences concerning the font and line attributes (font size and face, line spacing, etc.). If they have to read printed documents that are not adapted according to their needs they may use magnification devices such as magnifying glasses or video magnifiers to enlarge the area they try to recognise.

- Blind students cannot use their sight to read and use other senses to process information. The most common way is computer-based; therefore, they need digital editable documents to work with. Pieces of text and textual information about visual elements are reproduced verbally by a synthetic human voice or tactually on the refreshable braille display. This text-to-speech and text-to-braille service is part of a program called *screen reader*, the most important assistive technology for blind users of ICT which enables them to read/write electronic documents, e-mails, or textual data offered by operating systems or other programs, play audio or video files, work with common applications, etc. Some technologies work well with mathematical notation, which allows such students to study mathematics. Blind students may sometimes prefer to work with printed braille version of documents. Such a print can be produced by braille embossers and supplemented by tactile graphics replacing diagrammatic information such as schemes, graphs or maps.

People with visual impairment display differences in reading as they work in a linear way and are therefore able to follow a very limited amount of information at a time. However, mathematics and other STEM disciplines are very visual in their nature. When solving a mathematical problem we often receive input data/information. We may observe some of these items "concurrently and put them into suitable positions in space or a plane, which helps us understand the relationship between them better and enables us to work with them more effectively" (Másilko & Pecl, 2013, p. 99). This fact causes them to work at a slower pace with documents and applications if their reader/user needs to follow more than one source of information in parallel (Barnová et al., 2020).

When following the specification of the inquiry-based activity in written form, students with visual impairment need to receive instructions electronically, in editable format and well in advance in order to work with them using assistive technologies on their computers, laptops, tablets, etc.[6] They have limited opportunities to follow visual sources of information on black (white) boards or video projector screens or to understand the nonverbal activities of a teacher or students during the session.

Working in a group may be a challenge for the student with visual impairment and other members his/her team when they need to share results of their inquiry, for example to show others their computations, graphs, schemes. Having no access to what is being discussed, students with visual impairment may consider their active participation to be difficult as they do not have an idea of the problem's context. They display differences in using software applications and manipulating physical objects or instruments in laboratories. They need more time to familiarise themselves with the interface of programs and may need help from experts in assistive technology in order to search for effective ways to use them. They may need more time and individual help to learn how to work with instruments in laboratories. As for students with physical/mobility impairment, any non-standard arrangement of furniture and other

[6]We will summarise the requirements for accessible electronical documents later, in the chapter on Universal Design.

equipment in the classroom may cause an issue for the orientation and mobility of students with visual impairment.

4.5.7. Students With Hearing Impairment. Partial or total inability to hear is a common characteristic of people with hearing impairment (in other words with hearing loss, deaf or hard-of-hearing). They display differences in communication and may rely on spoken language with possible support by speech to text transcribers or the use of sign language and the need for an interpreter when 'talking'/listening to someone else. "Students with a hearing loss may require accommodations and assistive devices to have the best access to education. Accommodations may be as simple as preferential seating or as complex as wireless assistive listening devices in the classroom" (ADCET, n.d.). There is one more important aspect impacting on an individual's literacy and mathematics: the age of a person when s/he lost their hearing. We distinguish two groups of people with hearing impairment with regard to this aspect:

- pre-lingually deafened are those who lost their hearing before the development of spoken language;
- post-lingually deafened lost their hearing after they acquired language skills.

Most of the people with pre-lingual deafness experienced communication barriers during their pre-school age which influenced their language development. "Language deficits and differences have cascading effects in language-related areas of development, such as theory of mind and literacy development" (Lederberg et al., 2013).

When receiving the specification of the inquiry-based activity, many deaf or hard-of-hearing students are able to follow only one source of information at a time. They need a closer visual contact with the faces of speakers and minimised background noise in order to use assistive listening devices properly and/or have optimal conditions for lip-reading. Watching the teacher speaking and pointing at some part of formulae, diagram, or graph simultaneously is another big challenge for students with hearing loss as they have limited opportunity to follow more than one visual source and therefore can easily misunderstand the problem's context. For the same reason, they

- easily miss the beginning of a teacher's speech when they are focused on writing down their notes or making computations; and
- find it difficult to follow the teacher simultaneously speaking and demonstrating the use of some computer application or the manipulation with some instrument in a laboratory.

They may also display differences in working with different formats of information sources such as video/audio recordings or written materials. They may require the instructor to supplement such a video file with sign language interpretation or subtitles/captions. In case of audio files they may need text transcription. The language deficits may cause differences in getting oriented in extensive texts, interpreting information in wordy problems and tasks or producing their own written work. Students with hearing impairment may prefer visual learning strategies, such as organising information into diagrams or emphasising important facts by different colours, which fits with the nature of mathematics and other STEM disciplines.

Interaction based on discussions with members of one team may be a challenge for students who cannot hear the flow and nuances of rapid verbal exchange (ADCET, n.d.). It becomes even more difficult to react within a reasonable time if students with hearing loss follow sign language interpretation or speech to text transcription which is usually a few seconds delayed in comparison with speech flow during discussions.

4.5.8. Students With Disturbed Communication Skills. "Communication disorders can affect how a person receives, sends, processes, and understands concepts. They can have weaker speech and language skills, or impair the ability to hear and understand messages. There are many types of communication disorders" (Giorgi, 2019). There are:

- speech disorders—differences in articulation of speech sounds, fluency and/or voice (cluttering, stuttering, atypical production of speech sounds characterised by substitutions, omissions, additions or distortions, mutism);
- language disorders—differences in comprehension and/or use of spoken, written and/or other symbol systems (affect listening, speaking, reading, writing and doing math calculations);
- hearing disorders (more details in Section 4.5.7);
- central auditory processing disorders—deficits in the information processing of audible signals not attributed to impaired peripheral hearing sensitivity or intellectual impairment (more details in Section 4.5.2) (ASHA, 1993).

Students with disturbed communication skills need to receive an alternative to spoken instructions given by a teacher during the start of an inquiry-based activity. They prefer clear and structured information to the activity setting and its time plan in order to understand properly what they are supposed to do. They may need more time to research information sources.

Differences in communication may cause problems with active participation in discussions during small groups' collaborative work, presentation of results or final summary of the activity. They need more time to express their opinions or comments, to reply to questions and so on. They may be worried by other students' reactions to their verbal performance and such a concern may decrease the quality and fluency of the speech during the presentation of results in front of others. It is important to be patient and give frequent positive feedback in order to reduce their stress with 'public' speaking.

4.5.9. Students With Other Chronic Conditions. The last category of students with other chronic conditions seems to be the broadest one but when summarising their characteristics we can assume their needs as more 'organisational' in terms of their study as a whole without any specific projection to mathematics and other STEM disciplines. It is impossible to give a complete and structured list of all the chronic conditions. Let us name the most common among students with identified needs at universities: diabetes, autoimmune diseases of digestive tract (e.g., Ulcerative Colitis, Crohn's Disease, and Celiac Disease), migraine, tick-borne diseases (e.g., Borreliosis, Encephalitis), chronic fatigue syndrome, epilepsy, multiple sclerosis, and traumatic brain injuries.

Students with chronic conditions may take prescribed medication to regulate indicators of a disease. It can cause lack of energy, weariness, problems with concentration, memory and disturbed daily routines. Regular appointments with medical doctors or lengthy periods of hospitalisation may result in frequent nonattendance at lectures and seminars. Stressful situations like final tests and oral exams can worsen the symptoms of a disease and can cause mental health issues affecting the student's preparation for the assessment and his/her concentration/energy to successfully pass it.

Students with chronic conditions may need more frequent rest breaks during lectures and seminars to revive their energy or take medication. They prefer more flexible scheduling of homework and the delivery of projects. They need to optimise their time

schedule of lectures and seminars and set the dates for final exams in order to have enough time for preparation and rest (Barnová et al., 2020; ADCET, n.d.).

4.6. Universal Design of Inquiry-Based Mathematical Education

When we described pedagogical processes during inquiry-based instruction, we ordered them chronologically (Section 4.5.1). Later we tried to explain the differences between students with identified needs when they undertake any of these processes (Sections 4.5.2 to 4.5.9).

In this section, we introduce the readers to the principles of *Universal Design*, a methodology we can follow in order to create an inclusive learning environment reaching the needs of as many learners as possible. We will not offer a detailed explanation of the methodology. Instead, we try to project general principles of Universal Design onto the inquiry-based education of mathematics at universities. We will select/interpret the most important ideas of this methodology and offer them in the form of recommendations relevant to

- inquiry-based education of university mathematics, and
- students with identified needs and their active engagement.

4.6.1. Universal Design Principles. The fundamental design concept is called *Universal Design* and was introduced in 1985 by the architect Ronald L. Mace and his research group at the North Caroline State University as a "design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialised design" (Burgstahler, 2020b). The methodology is described by 'Seven principles of Universal Design': Equitable Use, Flexibility in Use, Simple and Intuitive Use, Perceptible Information, Tolerance for Error, Low Physical Effort, Size and Space for Approach and Use. Guidelines and examples of implementation according to the principles are available at (Burgstahler, 2015, 2020a; Čerešňová, 2018).

Universal Design for Learning (UDL) is a framework more closely associated with education. It was developed at the Center for Applied Special Technology located in Wakefield near Boston, led by Anne Meyer and David Rose. It aims to improve and optimise teaching and learning for all people based on scientific insights into how humans learn. UDL guidelines as an implementation of UDL is a structured set of suggestions and recommendations providing a reader with multiple means of

(1) engagement to support the motivation of learners,
(2) representation to address the needs and preferred learning styles of as many students as possible,
(3) action and expression to optimise the learning process and to offer a variety of options how to demonstrate knowledge and skills.

A lot of suggestions are proposed to reduce barriers to the educational process and create a learning environment more inclusive for students with identified needs. See more details at (CAST, 2018). We also refer to Section 6.7 of this book for a more detailed explanation of this framework and examples of the above mentioned UDL principles' implementation based on our own experience.

Accessibility of digital content is another big issue. The World Wide Web Consortium (W3C) is an international community leading the development of standards to ensure the accessibility of web sites and other digital documents including multimedia. The W3C Web Accessibility Initiative (WAI) produced detailed guidelines and other support materials to understand and implement accessibility. A lot of useful and practical information on this topic can be found at *Web Content Accessibility Guidelines*

(WCAG) or *Authoring Tool Accessibility Guidelines* (ATAG) based on the following essential principles:

(1) perceivable information and user interface (e.g., text alternatives for non-text content; captions and other alternatives for multimedia; content can be presented in different ways);
(2) operable user interface and navigation (e.g., users have enough time to read and use the content; users can easily navigate, find content, and determine where they are);
(3) understandable information and user interface (e.g., text is readable and understandable; content appears and operates in predictable ways; Users are helped to avoid and correct mistakes);
(4) robust content and reliable interpretation (e.g., content is compatible with current and future user tools) (W3C, Web Accessibility Initiative, 2021a).

Each of the following sections 4.6.2 to 4.6.8 focuses on one of the pedagogical processes during inquiry-based instruction (described in Section 4.5.1) and includes recommendations followed by additional resources. We offer these resources for two reasons: (1) as a source of the recommendations' interpretation/citation and (2) as a link to more detailed explanation of their implementation. Section 4.6.9 gives examples and general hints that might be useful when Universal Design is not enough and additional individual accommodations are needed for students with identified needs.

We believe some of these recommendations are well-known and respected by teachers of university mathematics. Based on our experience and supported by the general resources on Universal Design (Pollak, 2009; Burgstahler, 2015; Čerešňová, 2018), we can confirm the usefulness of Universal Design not just for students with identified needs, but for all learners.

4.6.2. Teacher's Talks and Presentations. Even though it is a student who conducts his/her learning during inquiry-based instruction, there may be situations a teacher talks in front of learners and shares visual sources of information on black (white) boards or video projector screens. It can happen at the beginning of the inquiry when the teacher gives instructions or during the final summary of the activity. We give several recommendations to facilitate the teacher's inputs:

(1) provide written instructions and other information resources ahead of time in a digital format, if possible in an editable version;
(2) speak clearly, minimise background noise, avoid unexpected moments of surprise or embarrassment (in motion, gestures, speech), keep eye contact with the audience when speaking, use a microphone, repeat comments and questions from others, wait a second to talk about details you refer to visually;
(3) cover all displayed text, describe visuals, comment on actions that can be recognised only by sight;
(4) enable video recording of your lecture, mainly the parts when all the participants communicate with one another;
(5) make sure everything is clear to students, i.e., convince them to create a summary of the goals and discuss the possible flow of activities leading to achieving them, indicate the time plan of the inquiry, give tips on useful sources or applications they can use during inquiry;
(6) enable different means of interaction during the talk (e.g., students may write questions and deliver them to you on paper or via shared document).

Additional resources: (W3C, Web Accessibility Initiative, 2021b)

4.6.3. Information Resources. The only way to meet the Universal Design principles when preparing information resources is to fix the content of any study and teaching material correctly in a digital way. For many reasons, described in Section 4.5, it is important to provide students with information resources well in advance. Such documents should not be based on just one perception 'channel' and should enable users' perception by different modalities (e.g., through vision, hearing or touch). Moreover, each of these 'channels' should be autonomous (i.e., clear for a person following just that 'channel'). Other recommendations are:

(1) create content that can be presented in different ways: use standard formatting tools, offer documents or multimedia in a flexible format to enable users to customise the display of the visual content (text, images, tables, etc.) such as its size, colour layout or contrast with the background, the volume and speed or timing of video/audio recordings and animations, the properties of a printed version;
(2) enhance the visual readability of a document, i.e., use larger character/word/line/paragraph spacing [follow the parameters indicated in the WCAG or (British Dyslexia Association, 2018)], set left alignment of the text (no justification), avoid multiple columns layout, underlining and italics, text in uppercase/capital letters, do not use colours as the only visual means of conveying information, define clearly rows and columns of a table and avoid using merged cells;
(3) help users navigate and find content, i.e., use headings and labels to describe the topic or purpose of the document's components (text, tables, images) and to organise the content, include a table of contents, consider using bulleted or numbered lists rather than continuous prose;
(4) make the content more comprehensible, i.e., provide clear instructions, give students a summary of goals, details of resources and knowledge they will gain, highlight how complex expressions are composed, summarise or visualise structural relations, provide readers with glossaries of abbreviations, new terms and symbols, unusual words (e.g., idioms, jargon);
(5) provide text alternatives for non-text (visual) content (images, video, animations, and so on);[7]
(6) provide captions and other alternatives for multimedia (e.g., captions for video documents or written transcripts for audio files);
(7) use standard tools to input maths symbols and enable access to the source of your mathematical document, usually created by a mark-up language such as LaTeX, MathML, etc.[8]

Additional resources: (W3C, Web Accessibility Initiative, 2021a; CAST, 2018; British Dyslexia Association, 2018; Čerešňová, 2018).

4.6.4. Collaborative Work and Projects in Small Teams. Learning how to communicate and collaborate effectively within small teams is a very important part of the educational process in order to prepare students for such situations that are very common in their future employment. It is easier for some rather than others as

[7] "The need for a description depends very much on the purpose of the visual information, i.e., pictures used for decoration may not need to be described, but pictures that convey meaning may need to be described" (Čerešňová, 2018).

[8] Students with identified needs may read/write mathematical expressions in special applications and need access to the document's source in order to convert it to the desired input format for such assistive technology.

students have different personal characteristics, communication skills and executive abilities (see details in Section 4.5). It is therefore a responsibility of a teacher to set out clear expectations of how the team inquiry should be organised. Moreover, s/he should carefully monitor all the processes of such peer cooperation and be prepared to help students if their collaboration gets stuck. Regarding students with identified needs a teacher should not pass her/his teaching responsibility to other people during the students' group work as such teams may easily behave inappropriately towards individuals with identified needs.

Teamworking may be a short in-class activity or a long-term project-based collaboration. In both cases, students with the help of their teacher should learn to accept and respect differences and abilities of each member of the team. We give several recommendations to facilitate group work so that the participants feel more comfortable during this type of learning activity:

(1) enable flexible rather than fixed grouping, ensure that no one is isolated or disadvantaged (allowing groups to self-select their members is not always the best policy);
(2) do not force participation in a group if it is possible to pass the inquiry activities without interaction and teamworking is not one of the main learning goals;
(3) define clearly goals of the inquiry, offer possible information resources and let the students know the time reserved for the activity;
(4) create expectations for group work and help students to establish their collaboration effectively (e.g., rules explaining your ideas on the team's organisation and all the participants' active participation, giving examples of the team member's roles and responsibilities, and so on);
(5) provide the team with constructive feedback which is frequent, in time, and specific;
(6) support long-term group work, i.e., provide checklists and project planning templates for understanding the problem, division of long-term goals into short-term objectives, setting up prioritisation, scheduling the activities including due dates and indication of who is responsible for the work.

Additional resources: (CAST, 2018; Pollak, 2009).

4.6.5. Software Applications to Gather, Analyse and Interpret Data. Students of mathematics and statistics are supposed to use statistical software, computer algebra systems and other specialised applications in order to manipulate data, perform their visualisations, analyse them and interpret their properties. A teacher should optimise access to such tools. As we described in Section 4.5, students with visual impairment and physical/mobility disabilities need help from experts—so they can use assistive technologies effectively when working with applications they have not used before. Such students may access applications only with keyboard and use keyboard key strokes for any mouse action. Blind users need to access applications via a screen reader while partially sighted students will zoom in on visual content using software magnifiers. This means providing text as a pure text (not as images), enhancing the quality of graphics so it is not distorted when magnified and giving appropriate text labels on all buttons, menus and menu items, icons, sliders, and all other interface objects (Čerešňová, 2018). All of this and much more should be examined by experts in assistive technology who may determine unexpected barriers and/or give advice on how to use specialised applications effectively.

On the other hand, there are different computer-based devices with different operating systems and any student, not only that with identified needs, may ask if s/he can use the tool with her/his computer, laptop, tablet, or mobile phone, and how the application interface looks like in order to be prepared and not solve any technological issue during inquiry.

We give several universal recommendations to facilitate using above mentioned software tools:

(1) let the students know well in advance about specialised software applications they will actively work with;
(2) choose and offer suitable support materials to help students with installation and ask them to familiarise themselves with the interface of the tools;
(3) consult accessibility of applications with experts in assistive technology in order to find the best option for students with identified needs.

Additional resources: (W3C, Web Accessibility Initiative, 2021a).

4.6.6. Physical Environments and Products. Appropriate classroom layout and placement of its elements should support the diversity of students and teachers, different activities and a variety of learning and teaching styles. During inquiry-based activities, when students interact in small groups or together with teachers, they might need to use computer-based devices in order to work with data, examine information resources, prepare outputs of their inquiry, manipulate physical objects and instruments in labs. Flexibility and adaptability of educational environment and its physical components is therefore the key requirement for inquiry-based instruction.

We give several universal recommendations a teacher should take into account when asking for a classroom or lab that best suits the different types of inquiry-based activities s/he plans with the aim of offering an inclusive and comfortable instructional space. Some of this advice is related to appropriate room utilisation and addresses the very important requirement of safety for students with identified needs which also applies to all students:

(1) ask for adaptable and movable furniture that can be arranged in order to enable effective communication of small groups undertaking inquiry;
(2) when arranging physical facilities try to minimise distractions and remember to return all equipment to its original position when finishing your lecture/seminar;
(3) eliminate elements and objects protruding from the walls that cannot be identified by a blind learner when using a white cane;
(4) check if the classroom layout including furniture allows sufficient space for manoeuvring of a person in a wheelchair[9] and convenient access to the equipment such as computers, lab instruments, and so on;
(5) check if you can modify lighting and acoustic conditions and give each student a clear line of sight to the instructor and visual aids used during instruction, and avoid strip lighting or flickering lights;
(6) ensure it is a suitable place for wheelchair users and do not separate them from other students, allow room for personal assistants, sign language interpreters, and speech-to-text transcribers.

Additional resources: (Čerešňová, 2018; Burgstahler, 2020a).

[9]The size of the manoeuvring space with wheelchair is 150 cm in diameter.

4.6.7. Discussion. Inquiry-based teaching and learning is based on asking questions, reflecting on given problems and their solutions. A teacher or students may initiate a discussion for different reasons: to make clear the goals of an inquiry, offer their own perspective and experiences with the inquiry's subject, advise on appropriate information resources and the tools needed for an investigation, reflect on students' or teams' findings, predictions or results, or to summarise activities. Hence discussions play a fundamental role during inquiry-based instruction and its participants should have an equal access to interact. Students with identified needs display differences in communication for different reasons described in Section 4.5 and it is therefore important to follow several recommendations in order to avoid unnecessary barriers and/or individual's concerns for interacting:

(1) establish a welcoming environment, encourage the sharing of multiple perspectives, value each individual's contribution and respond patiently so students will not be afraid to offer their opinion in front of others.
(2) indicate basic behavioural expectations and rules for common discussion so that all students can participate equally regardless of their communication differences and preferences;
(3) offer multiple options for communication, enable students to interact not only verbally, but also in written form (delivering questions and comments on a sheet of paper or online in a shared document or discussion forum) or another way (e.g., hands-on activities);
(4) pause slightly before letting other person speak so students have some time to process and summarise the information received and sign language interpreters or speech-to-text transcribers can finish the transfer of real-time spoken content to people with hearing impairment; and
(5) paraphrase a comment/question from a previous speaker or explain actions that can be recognised only by sight—it can help students with visual or hearing impairment or persons who did not understand all the details that were spoken/visualised.

Additional resources: (ADCET, n.d.; Burgstahler, 2020a; Pollak, 2009).

4.6.8. Students' Presentation of Results and Knowledge. Students often present results of their inquiry in front of their peers, sometimes informally (e.g., through discussions), sometimes more formally. If it is an assessed piece of work, they may have concerns about a lack of ability or opportunity to speak. Not only students with identified needs should know and understand well in advance all the teacher's expectations, presentation dates, what are the opportunities in case of the individual's or the team's failure. Such predictability together with flexibility of deadlines and variable opportunities to demonstrate the knowledge and skills can help to establish a more inclusive educational environment for students with mental health issues, specific learning differences and other identified needs:

(1) enable variability of informal and formal assessed presentations in order to give students opportunities to learn how to present their knowledge;
(2) give students alternatives to public on-site presentations if possible (e.g., posters or other types of written summary shared with others, pre-recorded video presentations, delivery of the presentation to the teacher only or by more than one student in case of a teamwork inquiry results presentation);
(3) ensure that time constraints are minimised and announce the date of the presentation well in advance (long-term projects) or give students/teams enough time to prepare a demonstration of the inquiry results (in-class activities);

(4) provide students with constructive and well-structured feedback which is delivered in time in order to improve their work and its presentation; give comments about the work and not the individual, proposals to change should be balanced by positive reflections. The feedback should be multi-modal such as written, audio or video recorded;
(5) offer corrective opportunities and options to resubmit the work or re-deliver the presentation in case students or teams did not meet your requirements.

Additional resources: (ADCET, n.d.; Burgstahler, 2020a; Pollak, 2009).

4.6.9. Individual Adjustments. "The goal of universal design is to create products and environments that are usable by everyone, regardless of ability or other characteristics, to the greatest extent possible, without the need for adjustments" (Burgstahler, 2015, p. 38). In other words, following the principles described in Section 4.6.1 should result in a more inclusive educational environment respecting students with identified needs as well as all students.. However, Universal Design methods are not always a perfect 'inclusion tool' for all educational situations and a teacher may still need to ask for individual adjustments to ensure the overall accessibility of inquiry-based activities s/he plans to organise. Preparing educational content according to Universal Design principles will be much more effective and help to facilitate the application of individual adjustments if they are needed.

Let's give some examples of such accommodations. STEM subjects are very visual in their nature and this brings challenges for blind and partially sighted students. Ensuring the accessibility of information resources full of mathematical symbols and diagrammatic information requires a collaboration with experts. A teacher and/or author of such study materials can help to make this process easier and faster if s/he follows Universal Design principles and recommendations listed in Section 4.6.3. Accessibility of specialised software such as statistical software or computer algebra systems for users with severe visual impairment or physical/movement disability is another issue which should be discussed with experts in assistive technology.

Another individual adjustment is related to communication. Students with hearing impairment may need a sign language interpreter or speech-to-text transcriber in order to understand the spoken information and also to have the opportunity to interact with other participants in lectures/seminars. Students with visual impairment or upper limbs impairment may need an assistant to help them manipulate physical objects and instruments.

All these examples of accommodations and many more should be provided by organisations established inside or outside the university but the teacher should be prepared to ask for such help. We give several recommendations on planning for individual adjustments for students whose needs are not fully satisfied by Universal Design principles:

(1) know how to get in touch with institutions responsible for individual accommodations, or at least university organisations offering the first contact to students who need help because of their learning differences, behavioural problems, mental health issues, and so on;
(2) collaborate with experts to help them deliver the individual accommodation in time and properly; and
(3) share information about accommodations with students and explain them (at the syllabus) how to ask for its.

Additional resources: (ADCET, n.d.; Burgstahler, 2015, 2020a).

4.7. Conclusion and Discussion

This chapter is focused on students with identified needs and their active participation in inquiry-based mathematics education. With respect to the social model of disability we considered the issue of inclusive higher education as a problem to be primarily solved by universities. Universal Design is the methodological framework which sits well for such a purpose and we briefly explained the main principles of this inclusion tool. Inquiry in mathematics can be understood as a continuous interaction between teachers and students which consists of several pedagogical processes. We investigated how students with identified needs participate in these processes and in which cases they may display differences. Based on our detailed study we prepared a list of recommendations for a teacher to implement in order to guarantee active and equal participation of students with identified needs during inquiry-based activities.

Furthermore, teachers may be in the same boat as students. While students undertake inquiry-based instruction, teachers inquire how to implement some of the Universal Design ideas into their lectures and seminars. Such development is continuous and clearly needs the feedback not only from students but also from experts on inclusive education in order to evaluate the effectiveness of implemented recommendations and plan other modifications of the course. We can certainly consider this scenario as an example of the developmental research described in (Artigue & Blomhøj, 2013; Goodchild et al., 2013) and the three-layer model presented in Chapter 2.

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