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VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ

FACULTY OF ELECTRICAL ENGINEERING AND COMMUNICATION
FAKULTA ELEKTROTECHNIKY
A KOMUNIKAČNÍCH TECHNOLOGIÍ

DEPARTMENT OF FOREIGN LANGUAGES
ÚSTAV JAZYKŮ

MEASUREMENT IN ELECTRICAL ENGINEERING – DIGITAL LEARNING MATERIALS
MĚŘENÍ V ELEKTROTECHNICE – DIGITÁLNÍ UČEBNÍ MATERIÁLY

BACHELOR'S THESIS
BAKALÁŘSKÁ PRÁCE

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Bakalářská práce

bakalářský studijní obor **Angličtina v elektrotechnice a informatice**

Ústav jazyků

Studentka: Michaela Ondráčková ***ID:*** 167669

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NÁZEV TÉMATU:

Měření v elektrotechnice – digitální učební materiály

POKYNY PRO VYPRACOVÁNÍ:

Cílem bakalářské práce je navrhnout a sestavit sadu digitálních učebních materiálů (pracovních listů a PowerPoint prezentací) pro výuku předmětu Měření v elektrotechnice tak, aby vhodně podpořily výuku předmětu v anglickém jazyce a bylo možné je ve výuce předmětu aplikovat.

DOPORUČENÁ LITERATURA:

1) Bartušek, Karel, et al. Měření v elektrotechnice - návody k laboratorním cvičením. Brno: Ing. Zdeněk Novotný, 2006.

2) Coombs, Clyde F. Electronic Instrument Handbook. New York: McGraw-Hill, 2000.

3) Průcha, Jan. Učebnice: Teorie a analýzy edukačního média. Příručka pro studenty, učitele,

autory učebnic a výzkumné pracovníky. Brno: Paido, 1998.

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ABSTRACT

The aim of this bachelor thesis is to present theoretical background for creating Digital Learning Materials for subject "Measurement in Electrical Engineering". The work focuses on the concept of digital learning materials and on the design methodology of digital learning materials. The thesis describes the learning requirements of the subject ("Measurement in Electrical Engineering"), necessary theoretical basis for creating didactic text and design requirements. Additionally, this bachelor thesis presents two designs of digital learning material, presentation and worksheet.

KEYWORDS

design methodology, digital learning material, laboratory exercise, Measurement in Electrical Engineering, presentation, textbook, worksheet

ABSTRAKT

Cílem bakalářské práce je poskytnout podklady pro tvorbu digitálních učebních materiálů pro předmět „Měření v elektrotechnice". Práce je zaměřena na samotný koncept digitálních učebních materiálů a na metodologii tvorby digitálních učebních materiálů. Dále se práce zabývá studijními požadavky samotného předmětu („Měření v elektrotechnice"), nezbytnými teoretickými východisky pro tvorbu didaktických textů a také požadavky na návrh. Navíc práce obsahuje dva návrhy digitálního učebního materiálu, prezentaci a pracovní list.

KLÍČOVÁ SLOVA

digitální učební materiály, laboratorní cvičení, metodika návrhu, Měření v elektrotechnice, pracovní list, prezentace, učebnice

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PROHLÁŠENÍ

Prohlašuji, že svoji bakalářskou práci na téma Měření v elektrotechnice – digitální učební materiály jsem vypracovala samostatně pod vedením vedoucí semestrální práce a s použitím odborné literatury a dalších informačních zdrojů, které jsou všechny citovány v práci a uvedeny v seznamu literatury na konci práce.

Jako autorka uvedené semestrální práce dále prohlašuji, že v souvislosti s vytvořením této semestrální práce jsem neporušila autorská práva třetích osob, zejména jsem nezasáhla nedovoleným způsobem do cizích autorských práv osobnostních a/nebo majetkových a jsem si plně vědoma následků porušení ustanovení § 11 a následujících zákona č. 121/2000 Sb., o právu autorském, o právech souvisejících s právem autorským a o změně některých zákonů (autorský zákon), ve znění pozdějších předpisů, včetně možných trestněprávních důsledků vyplývajících z ustanovení části druhé, hlavy VI. díl 4 Trestního zákoníku č. 40/2009 Sb.

V Brně dne ....

(podpis autorky)

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Table of Contents

1 Introduction

Creating any learning material is not an easy affair. It is rather challenging and it requires a great responsibility, awareness and certain rules must be followed. On the other hand, such work could be rewarding, because perhaps it might help someone to understand the subject matter better.

There are many means, which can carry the study material. The most spread and generally approved is the classical paper textbook. Nevertheless, the technology is developing fast and teachers have started to experiment with the new technology (the Internet, computers, etc.). However, there are not many handbooks on how to create a good digital material, which would fulfil the idea of a conservative textbook. Therefore, it is crucial to ensure that digital materials have the same functions as the textbook, as we know.

Digital learning materials propose a great variety of objects that a printed textbook cannot. To name at least some of the advantages: flexibility, interactivity, immediate feedback to the both teachers and students, easy accessibility, individualisation, economical reasons and others could be mentioned. Nevertheless, any of these previously named advantages could not be presented if required equipment (Information Communications Technology) is not implemented.

When creating study materials, one of the most important things to follow are the course requirements. It is necessary to stick to the curriculum of the given subject (in this case "Measurement in Electric Engineering") and in the case of digital learning materials, it can be customized for the learners.

Moreover, not only the contents is relevant, but also the design is very important and in the case of the digital learning materials it is highly desirable to deal with the design, and what is more the options are endless these days. However, the design should not be in the first place.

In the following chapters the creation and fundamental guidelines of designing and dealing with digital learning materials are discussed in greater detail. Additionally, two designs of digital learning material (presentation and worksheet) based on "Measurements in Electrical Engineering" course are introduced.

I. Theoretical Part

2 Concept of Digital Learning Materials

In terms of designing any Digital Learning Material (DLM) it is inevitable to present a concept of Digital Learning Material, which is considered to be a tool of more effective education, due to its highly appreciated advantages, mainly considering the connection of visual and auditory aspect of learning (for more see chapter *2.2 Advantages of Digital Learning Materials*). Furthermore, there is a need to describe the essential idea of Information Communications Technology, which is very closely connected to the whole concept of Digital Learning Material. (Rund, Šírl 6-7)

Information and Communications Technology (ICT)

ICT is very important concept for introducing the term Digital Learning Material (DLM). In fact, the whole concept of DLM rises from the fundamentals of ICT. The term "Information and Communications Technology" is according to Murray's article *Modern Network Architecture* "an extended term for information technology (IT) which stresses the role of unified communications and the integration of telecommunications, computers, middleware and the data systems that support, store and transmit communications between systems". ICT term includes not only hardware (telecommunications and networks) but also software and other systems. However, any definition could not be taken universally as "the concepts, methods and applications involved in ICT are constantly evolving on an almost daily basis", (Riley, *What is ICT?*). To imagine the nowadays significance of Information Communications System (ICT) according to Tongia's research into ICT it could be said that approximately two-third of the world economy is based on services and more and more commonly on ICT based services. (19-20)

Therefore, as a very good example of Information Communications Technology could be for common user understood personal computer including various types of software applications and network connection, more precisely the Internet. As Rund and Šídl claim, it is inevitable not to use a computer in educational process. Nowadays it is unimaginable that teachers would not use the computer. Hence, knowledge of fundamental computer software, such as operational system (OS) or simple text editor and Internet applications are required at certain level. In general, Rund and Šídl suggest that teacher could apply the computer in several means, PC could be used as a communication tool (emails, file sharing), as a self-education mean (E-learning), as the source of information (the Internet) or as a tool for creating learning materials (either digital or classic paper one). (10-17)

Digital Learning Materials (DLM)

A digital material is a material that exists in binary numeric form, as in digital audio or digital pictures. A digital learning material is any digital material that is used by teachers and students for the purpose of learning. The term "digital learning materials" is intentionally chosen to distinguish the material that can be studied from traditional textbooks.

According to Neumajer and his article "*Co jsou DUMy*, "The Digital Learning Materials are available in electronic form and could be implemented in tuition without no further adjustment. Usually those are worksheets, presentation, audio and video." He says that, digital learning materials could be compared with LEGO® bricks. Those bricks are componential as they could be variously combined and application manner depends on particular user. As with LEGO bricks, digital learning materials could be designed without elaborate methodological instructions, complex adjustments and any further software equipment. Neumajer on the server www.rvp.cz adds that, "Ideal Digital Learning Material do not substitute tuition fully, but it suitably complements and strengthens pupil's activity."

Digital learning materials are different from traditional textbooks in many ways. One obvious difference is that digital learning materials can be multi-modal, which means that the communication can be made both visually and auditory. Furthermore, visual presentations in digital format can be made not only as still pictures but also as short video sequences or animations. Another difference is that digital learning materials can be constructed as simulations, where the simulator represents a physical environment in which it is physically safe and not costly to make mistakes. According to *Beyond Textbooks. Digital Learning Resources as Systemic Innovation in the Nordic Countries*, the learning material could sometimes be turned into a representation of the subject matter, like a business or a farm. A digital learning resource is both an artefact and a semiotic tool with a bigger potential than traditional textbooks. (32)

In general terms, there does not exist very strict and precisely limited definition of the term "Digital Learning Material". According to previously mentioned assumptions, "Digital Learning Material" is any educative material in the digital (electronic) form available for tuition without further adjustment. Thus, it could be said that, this notion is very extensive.

2.1 Types of Digital Learning Materials

Used appropriately, digital learning resources can add considerable value to the quality of teaching and to the learner's experience. In general, we perceive digital learning materials as a certain type PowerPoint Presentation or interactive whiteboard, however there exist various types of digital learning materials, which could be implemented into the lesson.

The basic means of digital learning are mentioned in the following list:

1 **Presentations**
   - Interactive presentation created with software aid using special effects and design to catch audience's attention. (PowerPoint Presentation, Prezi etc.)

2 **Interactive Boards**
   - Interactive boards directly and, moreover, actively involve listeners to the learning process. (an example of interactive board editor could be the Workspace)

3 **E-learning**
   - Electronic learning is primarily based on the cooperation with a computer, which is frequently used as individual study resource. (an example of an e-learning platform which is used especially at universities is Moodle)

More detailed classification of digital learning materials is described in "Digital Learning Materials: Classification and Implications for the Curriculum" written by Ellen van den Berg, Peter Blijleven and Leanne Jansen. They divide types of digital materials according the activity. All of these activities can be used in all means of digital learning which were mentioned above (see p. 3-4).

Drill and Practice

According to Berg, drill and practice programs are the most well-known digital learning materials. (2) Even though drill and practice programs do not have good reputation at the present, they are essentially built on existing knowledge and give learners the opportunity to consolidate and repeat knowledge and train and automate acquired skills. Berg emphasizes that it is important to bear in our minds that the educational value of these programs (like all programs) depends on the quality of its instructional and technical design. (2)

Tutorials

Tutorials are completely contrary to drill and practice. Tutorials, in general, support above all the acquisition of knowledge and skills. They often apply immediate feedback to guide learning in an effective way. Berg says that, "The reputation of tutorials is better than that of drill and practice programs, although also tutorials fit more easily in a tradition of knowledge transmission then in more constructivist visions on teaching and learning." (2-3) Tutorials are very common in learning software applications and they might also serve instructional purposes in school subjects as well.

Multimedia

Berg defines multimedia as following, "Multimedia (or hypermedia) refer to programs that contain text, images and sound which are interacted in a non-linear structure." (3) They are primarily designed for the acquisition of knowledge as tutorials. The main difference between multimedia and tutorials lies in the organization of information: linear or branched sequences in tutorials and randomly sequences in multimedia programs. These multimedia programs usually have a large amount of the information codified in a non-text way, such as pictures, animations and video, which is especially appropriate in an ill-structured and complex knowledge.

Simulations

"Simulations are programs that contain a model of a system or a process." (Berg 4) It is desirable to learn the manipulation with variables when creating simulations. According to Alessi and Trollip there are two types of simulations. Either, simulations are about something or about how to do something (214). The former (physical simulations) focuses on an object or a phenomenon, the latter (procedural simulations), concentrates on a sequence of actions to reach a goal. Berg claims that the educational potential of computer simulations is high, because simulations optimally use the interactive possibilities of computer technology. (4) Moreover, simulations allow handling situations that would be too dangerous or time-consuming in real life.

Educational Games

Educational games are very closely related to simulations. Berg indicates, that the distinction between simulations and educational games is rather difficult (4). Berg defines the educational games with their characteristics: rules, points, winning and losing, coping with the pressure, skill and luck and so on. (4-5) The most significant feature of educational games is that they have a (often hidden) learning purpose and that knowledge and skills are imparted entertainingly into the game. Moreover, Berg points out "Educational games arose high motivation amongst learners." (5)

Tools

"A broad class of digital learning materials consists of computer tools which are basically developed to facilitate teaching and learning." (Berg 5) Berg also adds "These tools are not content-related, and most of them, such as word processing programs, are not designed with an educational purpose in mind." (5) It is rather difficult to formulate the classification of tools. Berg labels the computer tools in the following broad categories:

- database and encyclopaedias
- electronic performance support systems (EPSS)
- communication and cooperative environment
- new tutees

(5)

Obviously there exist larger variety of digital learning materials and more of them could have been mentioned and described in more detail. However, it is apparent that the validity of such learning materials types differs greatly and should be considered. Nowadays situation of very fast technology development changes things on the global level from day to day. New hardware equipment and new software are developed and those might not be suitable for some of the dated methods and types of digital learning materials anymore. Therefore, different types of materials mentioned above might not be up to date and even typical for current situation or for context and trends in education. More and more new methods and approaches to digital learning arises those days. Collateral conditions due to ICT development (Information and Communication Technologies) are opening great possibilities for teachers and educators in terms of designing customized learning materials, not solely strictly digital ones, suitable for one particular class or group of tutees.

2.2 Advantages of Digital Learning Materials

These days a demand for digital learning materials is rising due to a great deal of their advantages. As the technology is rapidly improving and computers are becoming more and more accessible the list of advantages of digital learning materials would be endless. Therefore it is appropriate to introduce the most important out of these:

- **Engagement**: Digital learning materials improve student's motivation due to the engaging content and game-based strategies.
- **Acessibility**: Digital resources are asynchronous enbling the learner to access them at any time, not just in the classroom, but anywhere anytime, therefore learning creates a new world of opportunity.
- **Time**: Digital learning extends the learning day and year, thus allowing students to learn when they learn best.
- **Flexibility**: It allows students to progress at their own rate; they can pause, fast-forward or rewind them reflecting their own preferences.
- **Individualization**: Digital learning allows customizing learning by level and modality.
- **Economical**: Digital learning materials in electronic form do not take up as much space as paper and can be printed at full quality without re-copying.
- **Data**: There are instant and multiple forms of feedback and smart profiles that will drive customized learning.
- **Easy innovation and actualization:** The teacher can update the content according to the educational requirements.
- **Sharing:** Digital learning provides the opportunity for teachers to share what works; students can discuss the problematics with their colleagues.
- **Ownership:** Students might choose what to learn and how to demonstrate their learning.
- **Parent involvement:** Digital learning provides parents with transparency and involvement in the classes in case of primary and secondary education

(Vander Ark, "10 Benefits & 10 Concerns About the Shift to Digital Learning")

Nevertheless, to present previously named advanatages in certain Digital Learning Material it is vital to implement the most important condition: to ensure the required equipment (ICT).

3 Design Methodology of Digital Learning Materials

The most important starting points for creating the content of digital learning materials are:

1. Analysis of learning requirements and audience characteristics (published in *ECTS Catalogue*):
   - Field of study: English in Electrical Engineering and Informatics
   - Subject: Measurement in Electrical Engineering
   - Occupational profiles of graduates: They will master spoken and written English at the level C1 of the Common European Framework of Languages focused on English language usage in electrical engineering and information technology.
2. Selection of the most appropriate forms of the content:
   - explanatory texts
   - exercises
   - demonstrations
   - images
   - etc.
3. Design, development and layout of the content:
   - arrangement
   - template Design
   - visual Elements

3.1 Learning Requirements

Learning requirements for the subject Measurement in Electrical Engineering are based on the ECTS (European Credit Transfer System). Firstly, it is necessary to describe a study programme and its requirements and then the subject requirements.

Study Programme Description

Following profile of the programme (English in Electrical Engineering and Informatics) is taken from official ECTS catalogue of Brno University of Technology. "The aim of the study programme is mastering of the interdisciplinary knowledge and skills provided by training not yet available on the market, though highly necessary in the view of the development and expansion of electrotechnical fields in the present globalising world, and considering the position of the English language as the global communication tool, which is particularly true for electrical engineering and information technology. The aim of the study programme is to equip the students with fundamental knowledge of electrotechnical study areas and particularly with the competences in professional language at the level C1 of the *Common European Reference Framework* (CEFR)."

The program provides graduates with certain key learning outcomes: "The graduates as the future members of this professional community will be provided with the knowledge and skills of reception as well as production of this functional variety." The programme includes "subjects focused on managerial skills which together with professional English, socio-cultural approach to the environment of English-speaking countries and knowledge of the fundamentals of electrical engineering and management will be good qualifications for careers in industry, administration, government institutions and scientific institutions."

Course Aims

The aim of the course is to provide students with information about methods for evaluating the accuracy of instruments and methods, about measuring instruments and methods for measuring active and passive quantities, as well as magnetic and non-electrical quantities.

Course Prerequisites

When regarding the study programme requirements, it is vital for the subject that students have knowledge of advanced English level as well as "knowledge at the level of secondary education and completion of obligatory courses taken in the first year of study at FEEC are required. Emphasis is placed on the knowledge of basic statistical methods, theoretical electrical engineering, signal processing, and analogue technology."

(*ECTS Catalogue*)

Course Learning Outcomes

Students who complete this course are able to (according to *ECTS Catalogue*):

- Evaluate the accuracy of the measuring method and instrument.
- Explain the construction and characteristics of standards of measuring electrical quantities.
- Be knowledgeable about the choice of suitable measuring techniques and methods, realise measuring tasks and evaluate measurement accuracy.
- Operate basic types of measuring instruments, oscilloscopes and counters.
- Explain the principle of converters realising mathematical operations, A/D converters, and D/A converters.
- Explain the principle of analogue and digital measuring instruments, evaluate their advantages and disadvantages.
- Be well informed in the choice of a suitable method for measuring active and passive electrical quantities, evaluate their advantages and disadvantages.
- Be well informed in the choice of a suitable method for measuring magnetic and non-electrical quantities.

Course Contents

The course is focused on measuring electrical, magnetic, and non-electrical quantities. In the first part of the semester, students are introduced to the basics of metrology in order to be able to evaluate the accuracy of measuring methods and measuring instruments, both analogue and digital. In subsequent sections the principles, structure and characteristics of measuring instruments, sampling, A/D and D/A converters, oscilloscopes and counters are explained. Almost half of the semester is devoted to methods of measuring voltage, current, frequency, time interval, phase, power, resistance, capacitance, inductance and resonant frequency, magnetic quantities, and non-electrical quantities. In laboratory exercises, students verify in practice the knowledge acquired in lectures: implementation of measuring methods, selection of appropriate measuring equipment, measurement proper, and accuracy evaluation via calculating the uncertainties.

Course Curriculum

1. Principles of correct measurement, standards of measuring electrical quantities.
2. Evaluation of the accuracy of analogue and digital instruments.
3. Uncertainties of direct and indirect measuring methods.
4. Measuring amplifier, its characteristic and use in measuring technology, converters for the realization of mathematical operations.
5. Analogue measuring instruments.
6. Digital measuring instruments, sampling, A/D converters, characteristics.
7. D/A converters.
8. Oscilloscopes.
9. Basic methods for measuring voltage, current, frequency, time interval, phase, and resonance frequency.
10. Basic methods for measuring power.
11. Basic methods for measuring resistance, capacitance, and inductance.
12. Magnetic measurement.
13. Measurement of non-electrical quantities. Automated measurement.

Type of Course Unit

- 13 hours lectures (optional)
- 13 hours laboratory exercises (obligatory)

3.2 Concept of a Textbook

First of all, it is crucially important to explain what a textbook is. The most simple but not completely satisfactory is to find a definition. When looking up the word “textbook” in a good online or paper-based dictionary, the following definitions may be found:

1. “a book that teaches a particular subject and that is used especially in schools and colleges” (*Oxford Advanced Dictionary* 1544)
2. “a book that contains detailed information about a subject for people who are studying that subject” (*Cambridge Online Dictionary*)
3. “a book about a particular subject that is used in the study of that subject especially in a school” (*Merriam-Webster Online Dictionary*)

All the above-mentioned definitions are too broad and concise for somebody who wants to deal with the topic of a textbook in further detail. Some pedagogical experts provide more comprehensive and precise definitions of a textbook, such as:

1. A textbook is based on a curriculum content standard which defines and specifies the content and extent of the given subject in the sequential year of studies. (Wahla 12)
2. A textbook is a means of teaching and learning in a book form containing certain specialized topics and areas of the given subject methodically arranged and didactically depicted so that it enables learning. (Eberle 259)
3. A textbook is a teaching tool for teachers and students, which includes appropriately modified educational content. Since it is approved by the Ministry of Education, it represents an important educational document. Textbooks have a didactic and organizing function. (Janiš 36)
4. “… books that were created intentionally for teaching and learning, as well as other written materials used in the classroom.” (Laws 28)
5. A textbook is a kind of book publication adapted for a didactic communication in its content and form. (Průcha, Walterová, Mareš 387).

All these definitions are unambiguously correct but unfortunately incomplete. The definition of a textbook itself is much more complex than it may seem. It is necessary to proceed from the general classification of a textbook to its distinctive features. Therefore, the integration of a textbook within the educational system is required. Průcha characterizes a textbook within the educational system as:

a) Curricular document:

- Every textbook should be restricted by the curriculum according to the students' ability (defined by the curricula).
- Educational programmes rely on the existence of textbooks as well as on the fact that pupils and students are well-informed about them and able to work with them – work with a text is one of the key competencies defined by the *Framework Educational Programme* for all stages of education.
- In general, textbooks are a part of curricular documents and therefore they are also a part of validated educational programmes.

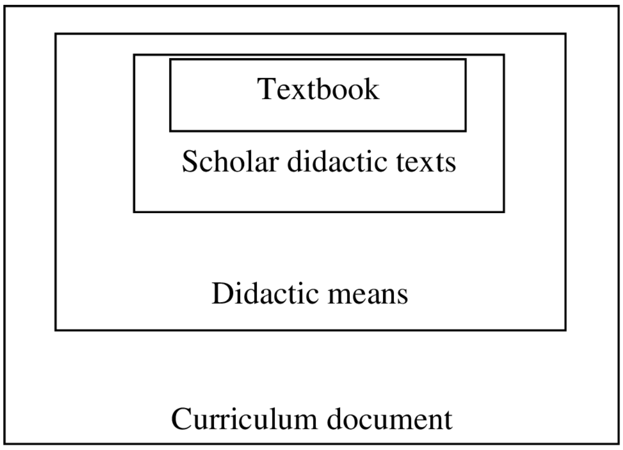

Figure 1. Textbook classification within curricular system (taken from Průcha 1998)

b) Didactic tool:

- It is also essential to examine a textbook with regard to other competitive didactic means such as multimedia presentations, electronic textbooks and others.
- It is a tool that helps to achieve learning objectives and realizes education itself.
- Nowadays the use of textbooks is related to the use of audio-visual equipment (interactive textbooks, videos, audio, animation, etc.)

c) **Type of a didactic text:**
   - A textbook is one type (the most widespread) of didactic texts constructed usually as a book.
   - The current trend suggests a combination of several types of didactic texts, for example, a publication of interconnected sets compiled of student's books, workbooks and teacher's books.
   - Didactic texts also differ according to the level of education for which they are designed (texts for elementary schools, secondary schools, specializes schools etc.).

(13-16)

It is very important to remember that textbooks do not exist only in the form of a printed and bounded artefact because a great variety of other, in particular e-learning materials, have emerged, which are gradually substituting the traditional textbook. These electronic materials are in fact widely spread and available in almost every school due to the unlimited and easy Internet access. Therefore, it is necessary to modify the existing definition of a textbook which has been used for decades. A redefinition of a textbook should embrace every aspect of both classical and modern conceptions of a textbook. As a result, a modern textbook could be described as following:

Textbook is defined as a comprehensive learning resource that is in print or electronic form, or consist of any combination of print, electronic and non-print materials collectively designed to support a substantial portion of national curriculum expectations for a specific grade and subject in scholar system. Such a resource is intended for use by an entire class or group of students. (Ministry of Education 3)

3.2.1 Function of a Textbook

Some may argue that a textbook is generally an element in a larger instructional design (e.g. a course). However, a textbook has different roles within the educational and cultural system; therefore different functions of a textbook should be taken into consideration.

Maňák points out that the most general function of the textbook is a role, an intended purpose, which such a didactic means should fulfil in a real educational process. (19). Průcha divides textbook functions according to subjects, which use textbooks. For this reason, he distinguishes two roles of the textbook according to its end user:

- **Students:**
  A textbook is a source of information, skills, competences, values, norms and attitudes.
- **Teachers:**
  A textbook is a source for planning the curriculum, direct presentation of its content in classes, and evaluation of educational results of pupils and students.

(19)

The most detailed classification of a textbook function was formulated by Dmitry D. Zuev in his book *Школьный Учебник* in 1983. He and his colleagues applied the so-called the functionally structural analysis and with the help of Nina F. Talyzina's psychological theory of learning they differentiated eight basic functions of a textbook:

- **Informative function:**
  A textbook defines the boundaries of the educational content in a particular subject or field of study including the quantity of knowledge that students should acquire.
- **Transformational function:**
  A transformational function is determined by the fact that a textbook offers scientific information that is transformed into an easier and understandable form.
- **Systematic function:**
  A textbook divides the curriculum according to a complex system into the individual grades in a school and defines the sequences of the individual parts of the curriculum.
- **Consolidating and evaluative function:**
  A textbook allows students to acquire some knowledge, practise, consolidate and evaluate the acquirement.
- **Self-education function:**
  A self-educational function leads students to individual and independent work with the textbook and generates primary motivation and needs that are important for cognition.
- **Integration function:**
  A textbook offers the basis for comprehension and integration of knowledge that students gain from other sources.

- **Coordination function:**

  A textbook provides coordination when using other didactic aids that are related to the textbook and relates to it.
- **Formative-educational function:**

  A textbook contributes to the development of the individuality of pupils and students.

(67-68)

The above-mentioned survey indicates that there are many functions of a textbook; however, not all of them are included in every textbook. To fulfil these missing functions supplementary didactic materials, such as worksheets, digital learning materials and video, are often used.

3.2.2 Design of a Textbook

The aim of textbook design is to present to the reader some guidelines how the textbook is structured. According to Zuyev, textbook is a hierarchically structured system whose closely interrelated particular components fulfil various textbook functions through the specific means of expression. (95)

Průcha presents the general model of textbook design (21):

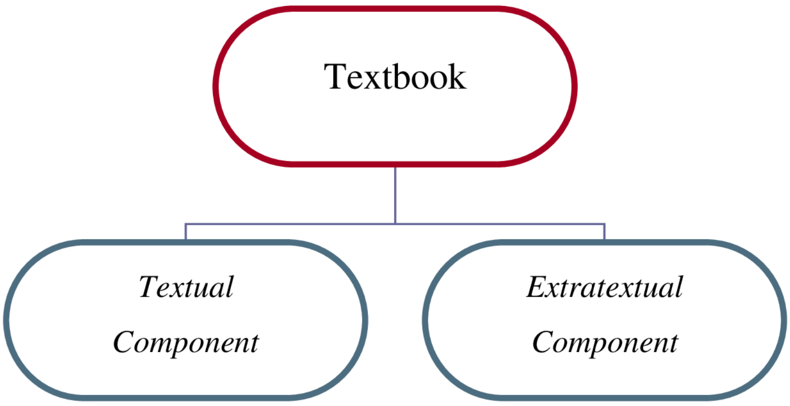

Figure 2. Textbook function strucutural analysis
(taken from Průcha's *Učebnice: Teorie a analýzy edukačního média*)

Textual components were further analysed by J. Doleček, M. Řešátko and Z. Skoupil. They classified structural components, more precisely by defining seven textual components, based on their functions.

Textual Component	*Component Function*
1 Motivational text	Introduces and at the same time explains the importance of the curriculum. Activates the learners.
2 Explanatory text	Communicates knowledge, facts, theory, norms, values, attitudes etc.
3 Regulatory text	Activates the learner while reading (gives instructions etc.)
4 Demonstrations and examples	The function is not defined by the authors
5 Exercises	Results in intentional revising of certain activity and acquiring skills and habits etc.
6 Questions	Activates common functions as in 5
7 Feedback means	Acquires information about learning process (for example: keys to exercises)

Table 1. Textual Components and their Functions
(taken from Průcha's *Učebnice: Teorie a analýzy edukačního média*)

(Průcha 21)

According to Hartley, as extratextual components we can consider:

- page size
- type size and spacing
- typefaces
- illustrations
- tables, graphs, diagrams and symbols

(Hartley et al.)

3.3 Theory of Multiple Intelligences

In terms of designing any educative material, it is necessary to take into consideration at least some studies on elementary concepts of acquiring knowledge, intelligence and individual learner's need. There were established several theories how people learn. The most well-known model is based on distinguishing three general categories of learners: visual learners, auditory learners, and kinaesthetic learners. As Northern Illinois University declares, beyond these three broad categories, many theories and approaches toward human potential have been developed. Among them is the theory of multiple intelligences, developed by Professor of Education at Harvard University, Howard Gardner, Ph.D.,.

(NIU, Faculty Development and Instructional Design Center 1-2)

Multiple intelligences were introduced by Howard Gardner in his 1983 book *Frames of Mind: The Theory of Multiple Intelligences.* Gardner's approach to intelligence transformed not only the meaning of the word itself, but most significantly, it modified whole understanding of the term. He argues that, there does not exist solely one intelligence and that child or an adult could be good only at one specific field (e.g. mathematics). On the contrary Gardner suggests, that there is even more than 8 intelligences which are represented by different proportions. (3-5)

Howard Gardner in 1993 revised his theory and add two more multiple intelligences (*Multiple Intelligences: New Horizons*), accordingly:

1 **Musical Intelligence:** ability to produce and sensitivity to rhythm, pitch and timber.

2 **Bodily-Kinaesthetic Intelligence:** ability to control one's body movements and to handle objects skilfully.

3 **Logical-Mathematical Intelligence:** ability to think conceptually and abstractly, and capacity to discern logical and numerical patterns.

4 **Verbal-Linguistic Intelligence:** well-developed verbal skills and sensitivity to the sounds, meanings and rhythms of words.

5 **Spatial-Visual intelligence:** capacity to think in images and pictures, to visualize accurately and abstractly.

6 **Interpersonal Intelligence:** capacity to detect and respond appropriately to the moods, motivations and desires of others.

7 **Intrapersonal Intelligence:** capacity to be self-aware and in tune with inner feelings, values, beliefs and thinking processes.

8 **Naturalist Intelligence:** ability to recognize and categorize plants, animals and other objects in nature.

9 **Existential Intelligence:** sensitivity and capacity to tackle deep questions about human existence.

(8-21)

At the present nine Multiple Intelligences are known, nevertheless on January 13, 2016 Gardner mentioned in an interview with *BigThink* (https://www.youtube.com/watch?v=oY2C4YgXm7I) that he is considering to add another intelligence, named the Teaching-Pedagogical Intelligence "which allows us to be able to teach successfully to other people". At the same interview, Gardner refused other suggested intelligences, e.g. humour or cooking.

Previous multiple intelligences illustrates how complex it is to create a learning material that will be suitable for everyone, according to their personal needs, meaning intelligences. According to Gardner, it is known that each person have every intelligence represented by different ratios, therefore it is very important when designing a learning material to present suitable elements to address as many multiple intelligences as possible. (6-8)

3.4 Criteria for Design of Digital Teaching Materials

Both content and form are important aspects when designing digital teaching materials. However, formal aspect is in case of digital learning materials even more important since teachers always know very well what content should be presented to their students. According to Duarte, the basic elements on which success of a presentation depends are arrangement, visual elements, creating movement and governing with templates. (81-202)

3.4.1 Arrangement

In the art of creating new digital materials, it is highly important to consider an arrangement. Nancy Duarte points out that arrangement can evoke feelings of tension, confusion, and agitation. On the contrary, it can ensure clarity by employing the following:

- **Contrast:** The audience can identify the main point quickly.
- **Flow:** The audience knows the order in which to process the information.
- **Hierarchy:** The audience sees the relationship between elements.
- **Unity:** The audience senses that the information belongs together.
- **Proximity:** The audience perceives meaning from the location of elements.
- **Whitespace:** The audience has visual breathing room.
- **Template Design:** The audience discovers certain beauty in the design.

(92)

These are the tools for assembling a great slide without paying further concentration to each of these issues. Fortunately, all of these are intuitive concepts, which may be used without author's awareness.

It is vital to remember that every slide should start and end with a very specific idea. It is crucial to rebuild abstract ideas into a form, which would be more digestible to the audience. In simpler terms, ideas should be "decoded" and it is always the presenter's responsibility to do so. It frequently occurs that presenter illustrates more than one idea on only one slide and therefore each idea is attached equal value. Also it is very important for the presenter to determine which element should be dominant and which elements can be restrained. Overcrowding slide leads to ambiguities of the message. We simply need to make a decision about the priority of the information. As Nancy Duarte says: "It's laziness on the presenter's part to put everything on one slide." (93)

In Nancy Duarte's book *Slide:ology* a lot of attention is given to these elements. In the following section the most relevant information is introduced.

Contrast

Designer Paul Rand says that, "Without contrast you're dead." (Duarte 95). Contrast is a really essential matter of every presentation. Viewers of every presentation need to find a contrast. They need to identify the main points immediately and focus their attention. To focus someone's attention it is necessary to create notable differences. There are many ways how to highlight an element on a slide, by changing the size, shape, shade, colour, and proximity of the element. It is important to establish relationships between slide elements. A common mistake is when a contrast is assigned unintentionally, which can lead to perplexity of the intended message. We need to remember that all stylistic choices have the potential to suggest importance, urgency, and value.

Flow

Flow is another highly significant aspect of a presentation. We need to realize that humans tend to read from left to right using so called a Z-shaped pattern (see fig. 1). This type of reading is for people intuitive and it induces a natural eye movement. In terms of satisfying their needs, it is essential to follow this pattern. This applies also for the images and diagrams, they should have clear directional flow too. Duarte says (98), that you should organize slides to guide the audience's eyes through the content in an obvious way.

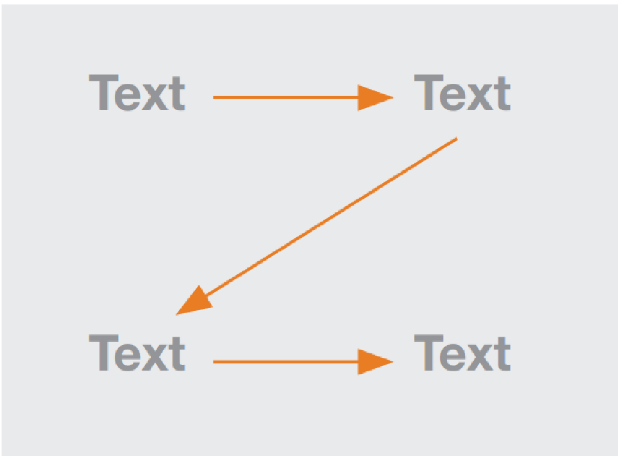

Figure 3. Z-shaped pattern (taken from Duarte's *Slideo:logy*, 2008)

Hierarchy

A visual structure mirrors the structure of the information it represents. It is required that audience see relationships between elements. An audience processes hierarchy as quickly as contrast, in particular visual hierarchy is very easy to recognize at first sight. As an example of visual hierarchy, Duarte suggests that title should act as a parent and the text that follows is as its children. (98) Therefore, we can estimate that size together with location indicates significance. By changing the size and proximity of objects, their visual story is modified.

Unity

Unity in general facilitates the audience to sense the structure of information. Unity can be achieved by structuring elements into a grid, by changing the look (graphical style) and theme (the big idea behind a presentation). It is vital that presentation in terms of structuring is original and unique. Duarte suggests creating a grid, which would provide a flexible way how to organize content (such as a block of text or an image). (100) This stability helps the audience correctly identify patterns in the placement of content which also helps the audience anticipate where content will appear. Grids also allow to hold certain design theme not only for corporations and institutions but also for individuals who would reapply slides when they are similar and follow a basic grid system.

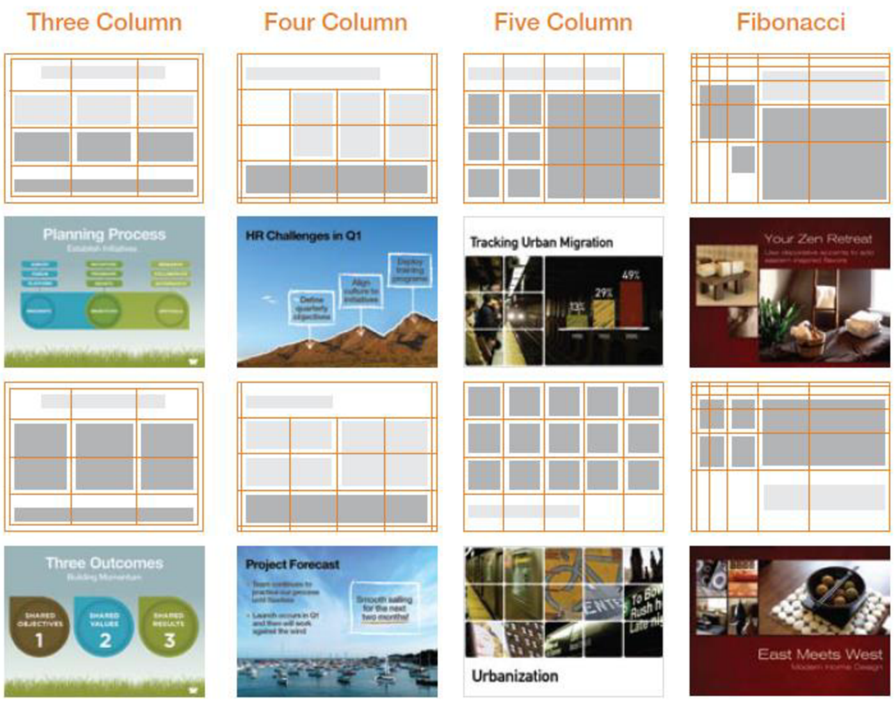

Figure 4. Examples of grid structuring (taken from Duarte's *Slideo:logy* 2008)

Proximity

The concept of proximity conveys an idea that we should perceive meaning also from location. Duarte says: "When more than a single element or person appears in a scene, their placement relative to each other tells a secondary story to the image itself." (104) Therefore, we need to consider two proximity types: space proximity and people proximity, both of which have a significant influence on perceiving the presentation.

Most important for creating the presentation is probably space proximity. By organizing the elements in certain relationships, which might suggest unity or fragmentation, order or chaos, equality or inequality, presenter should avoid the audience from making unintended interpretations.

Whitespace

Duarte subtitled this chapter as "Getting Visual Breathing Room". On the one hand, it is true that the visible elements usually receive the most focus, but on the other hand, it is vital to pay attention to how much space is left open, often referred to as whitespace, negative space or clear space. Whitespace is not necessarily white; it refers to any empty areas on the slide. The rule is that "it's okay to have clear design – clutter is a failure of design" (Duarte 106). The solution how to respect this rule is to keep in mind that the amount of information the presentation contains should be not quantitative but qualitative, not vice versa. Slides should convey a simple message which an audience would understand as the key points. Otherwise, the audience would find it very difficult to comprehend and orientate in the presentation.

A very good example how to understand the need of whitespace comes from Garr Reynolds, who believes that "design isn't about decoration or about ornamentation. Design is about making communication as easy and clear for the viewer as possible." (Duarte 109). And he compares a good presentation with sufficient amount of whitespaces to a Zen garden. He says that "A Zen garden is also a lesson in simplicity. Open space without ornamentation, a few rocks carefully selected and placed, raked gravel. Beautiful. Simple." (Duarte 109)

Template Design

A design of every presentation is probably the most important factor of all because there is a need to attract the audience at the very first moment. Elements should be arranged carefully with an intention, which creates special meaning and purpose. Presentation should never be considered a mess, too much of everything. Considering the usage of template design when creating, we need to remember that it is almost the same as with graphic design, product design or even with architecture. There are always reasons behind the usage of certain colour, typeface, and particular placement of an element. Of course, after having some vision of a particular design, a contrast, flow, hierarchy, unity, proximity and space must take place. This all is not as feasible as it might seem. Designers of templates should carefully plan out the exact journey if they want their audience's eyes to travel across the arrangement. Obviously, the elements that do not place emphasis on your point should be removed.

3.4.2 Visual Elements

Visual elements are another essential constituent of a very good presentation. After determining the basics of arrangement, it is vital to identify the visual elements and realize how cooperate with them and take advantage of their usage. The basic visual elements, which should be considered when creating any presentation are: background, colour, text, images, and animations. Duarte says that each ingredient – background, colour etc. – determines how your slide elements will look and requires that key design decisions should be made and only then the arrangement of components, such as contrast, flow, etc., could be applied. (114) There is never only one right theme, but the only thing they should have in common is consistency. An element style should be wisely chosen and the author should stick with it.

Background

"A background is a container or surface on which to place visual elements. It can incorporate anything you want, or it can have nothing on it at all." (Duarte 116). Background environment should not be used out of simple templates but should be more personalized according to factual needs of the presenter. "Backgrounds are intended as a surface on which to place elements. They are not in themselves a work of art." (Duarte 118). And finally not to forget that background should never compete with content.

Colour

It might seem that colour is not as important as other elements such as text, for instance, but the fact is that colour is considered crucial in terms of creating a presentation. Colour sets tone and helps to establish audience's expectations. Colours should be chosen appropriately to represent a presenter's personality, company, purpose or stance. Duarte considers important for presenters to ask themselves these three questions before choosing the right colours: Who is your audience? What is your matter? Who are you? (126) When deciding the colours, Duarte suggests to use "Colour Wheel", or take advantage of Using Industry Colour Pallets.

Text

Duarte assimilates presentation to billboard and names presentations "a glance media" (140). It means that audience should be able to quickly ascertain the meaning before turning their attention back to the presenter. A message should be effectively processed within three seconds solely. Duarte point out "Content should lend itself to quick processing, and should be typeset correctly." (141) Text is a fundamental part of our culture and therefore most people can inherently and easily recognize when a text is balanced and used well.

There is no official rule how many words could be on one slide. Generally, there should be enough words to deliver message comfortably. Words should work as mnemonic tool for the presenter, but only with very low word count.

Images

Images are a part of visual elements which can be divided into two subcategories: illustrations and photographs. The most important condition is that images must be presentation matching. They must have something in common with the presentation and sometimes it is challenging to choose an appropriate image for a presentation. When cropping a picture, it is necessary to leave the most important part of a presentation. There are also certain rules if taking own photographs, although having own pictures is always better then authorizing others.

Handling with images might seem as a job for a professional photo editor, because there are certain procedures how to edit photographs. Nevertheless, nowadays there are tons of different photograph editors.

Animations

It is commonly known that the main purpose of using animations in presentation is to catch an audience's attention. These days, presentations are daily-based concern and it is really tempting to make everything moving in a presentation. Unfortunately, it is not desirable. Duarte implies that "if animation is incorporated without purpose or meaning, the audience's attention is turned away from the presenter and toward the movement". (154) Every change creates distraction and presenter should be aware of it. Using animation is not a bad thing, however animations should be wisely chosen according not only to topic but also considering the message it will deliver to the audience. Animation is a key point strategy, not only visual effect without a meaning. Every element in a presentation has a meaning. Duarte suggests: "If choosing animation, it should look natural and alive, movement of objects should seem familiar and make sense." (155)

II. Practical Part

4 Procedure of Designing Digital Learning Material

Elementary methodology of designing digital learning material was discussed in previous theoretical part. From what was presented previously, it is known that methodology is essential and could not be omitted in terms of designing any DLM.

As it was already described, and according to Diederen's et al. *Design and Evaluation of Digital Learning Material*, "ICT provides several opportunities to approach problems with respect to efficiency, frustration and motivation of the classes on quantitative aspects. To take advantage of these opportunities, it was decided to design and develop digital learning material". Moreover, Diederen et al. say that, in general the design process starts with the description of design guidelines and design requirements based on theories of learning and instruction. To sum up the elementary theory and requirements were fully described in theoretical part of this work. (497)

For actual designs were selected two most frequent types of digital learning material, presentation and worksheet. Following designs are based on the laboratory exercise 1A adapted from *Měření v Elektrotechnice – návody k laboratorním cvičením* written by Bartušek et al. As a default design of outline was chosen the new visual style of Brno University of Technology (BUT), according to *Manuál jednotného vizuálního stylu VUT v Brně*. Some elements presented in templates offered by BUT, such as logos, background template, colour scheme were used in following materials.

5 Presentation Design

5.1 Annotation

Following presentation design is addressed to university students of Brno University of Technology, Faculty of Electrical Engineering and Communication. The material is to be part of subject "Measurements in Electrical Engineering". The aim of the presentation is to prepare students for the laboratory exercise, *1A Instrument Accuracy Verification,* and introduce elementary concepts of accuracy verification. The presentation is intended to be studied at home before actual measuring, laboratory exercise. Material was not approved by any authority in the field of study (measurement in electrical engineering). Presentation is interactive, using several hypertext links and videos. Part of the presentation is also activating element in the form of questions. Presentation was designed using Microsoft Office Power Point tool. (Note: Actual presentation is included on the CD attached to printed version of bachelor thesis.)

5.2 Actual Design

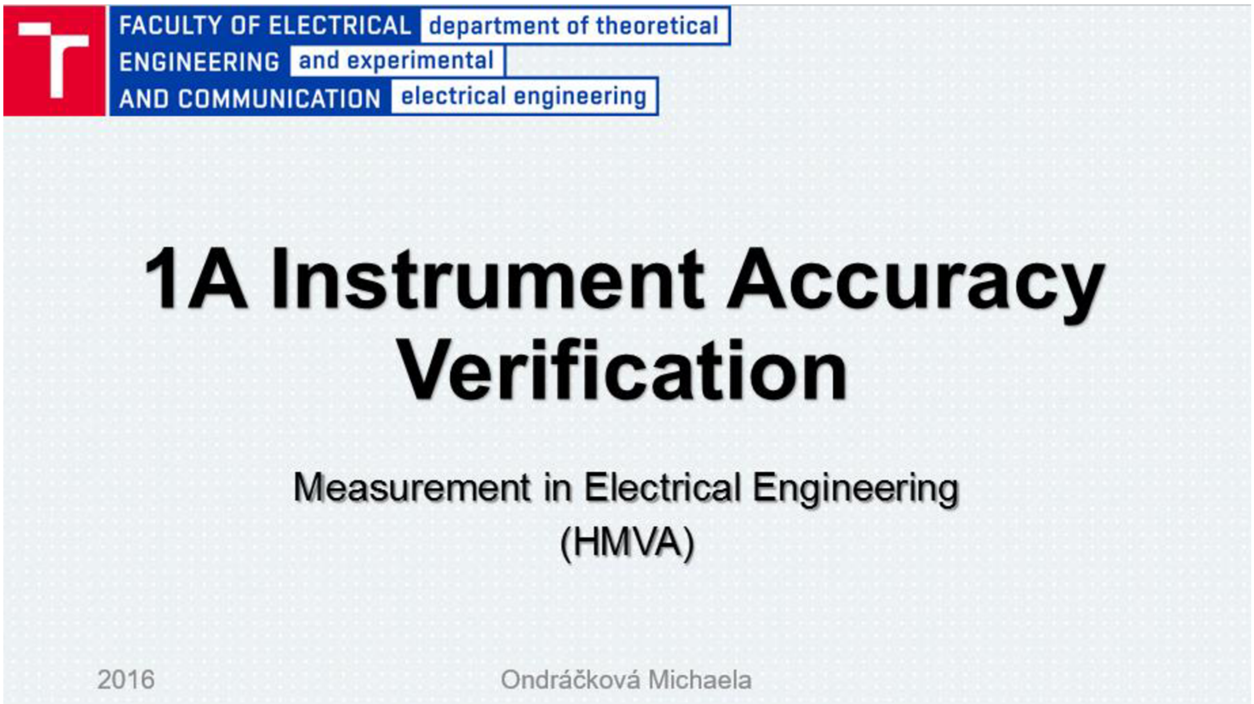

Figure 5. *1A Instrument Accuracy Verification .ppt*, slide 1

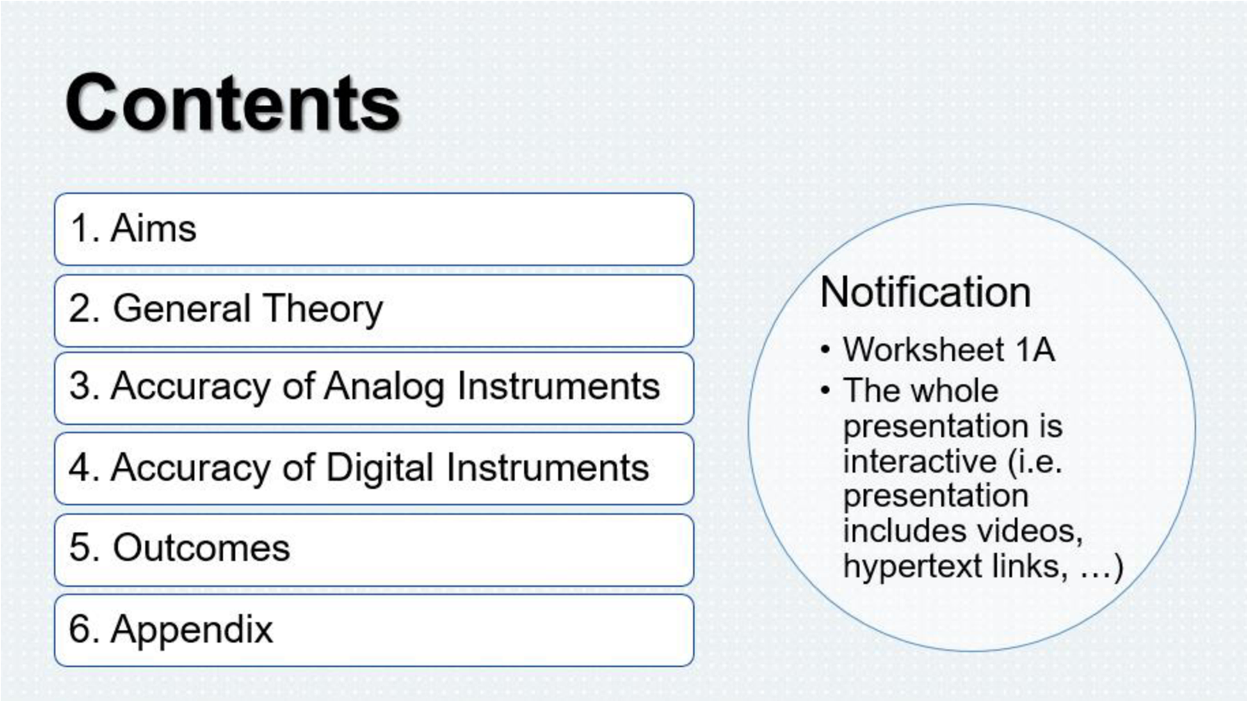

Figure 6. *1A Instrument Accuracy Verification .ppt*, slide 2

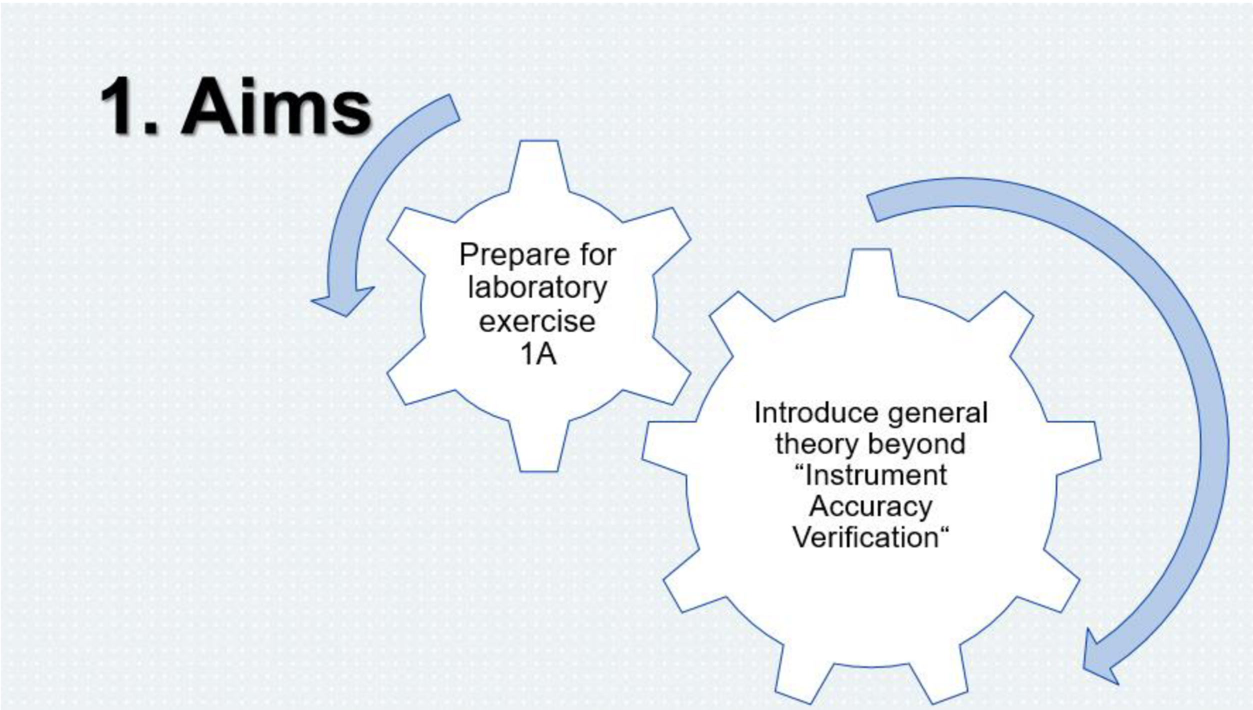

Figure 7. *1A Instrument Accuracy Verification .ppt*, slide 3

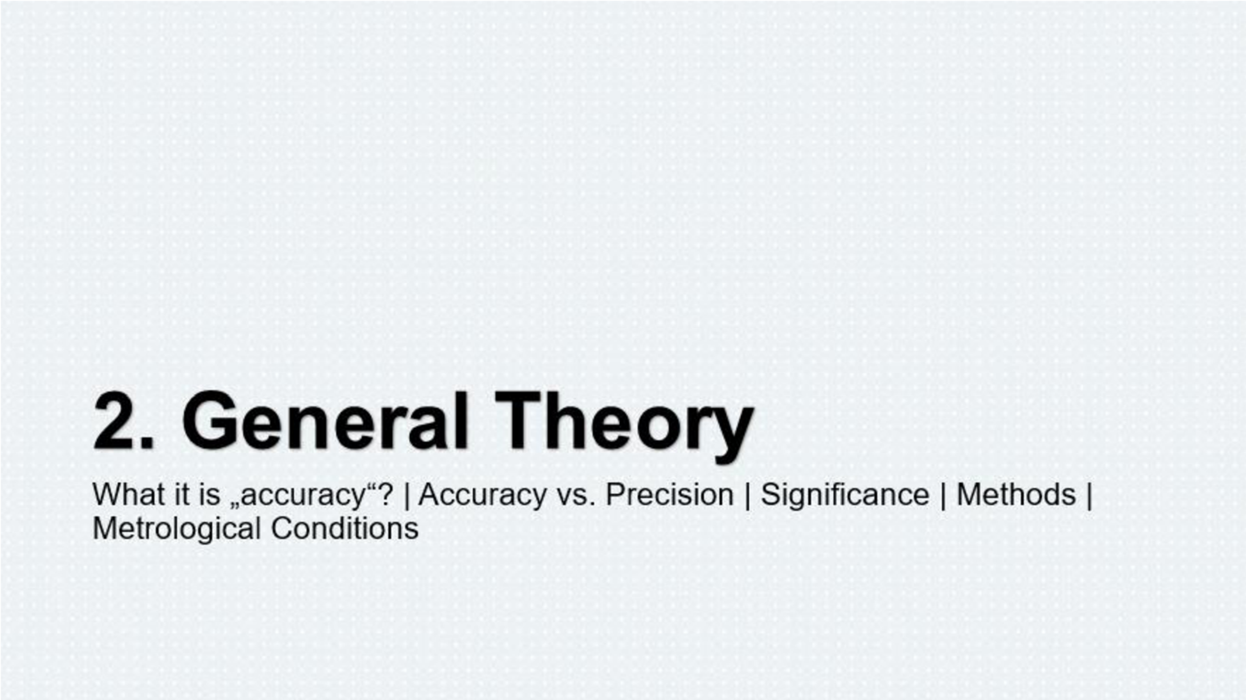

Figure 8. *1A Instrument Accuracy Verification .ppt*, slide 4

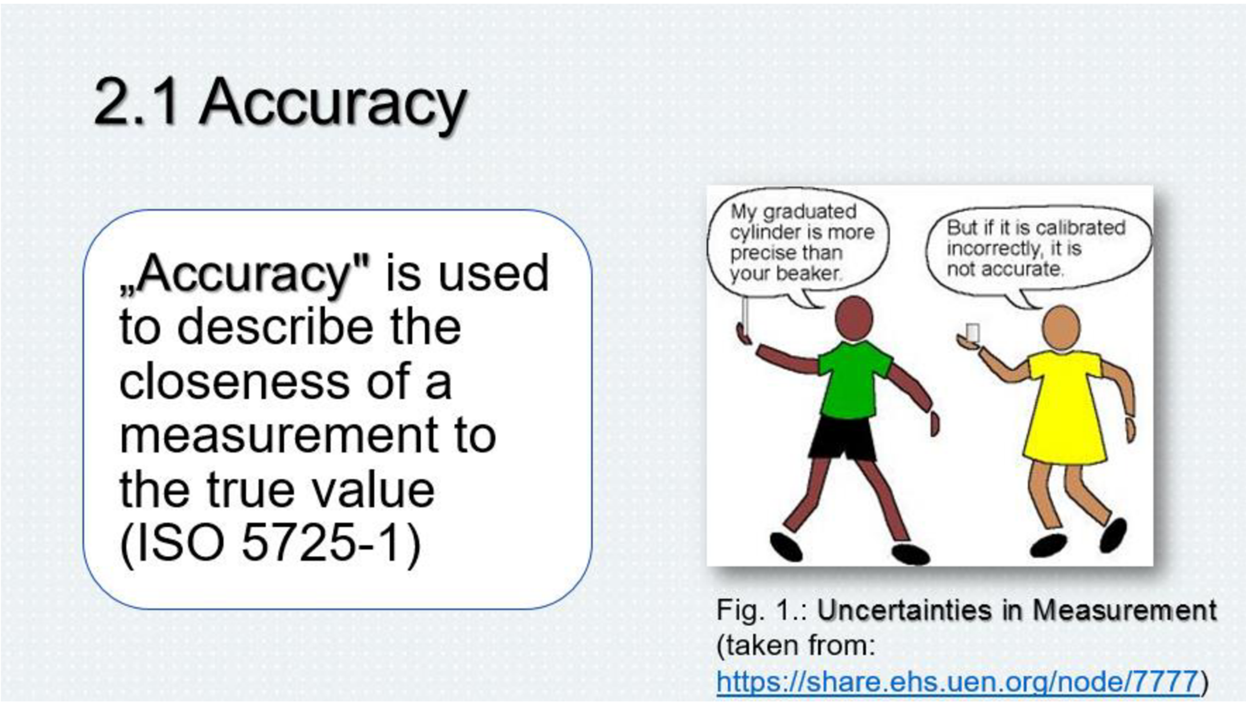

Figure 9. *1A Instrument Accuracy Verification .ppt*, slide 5

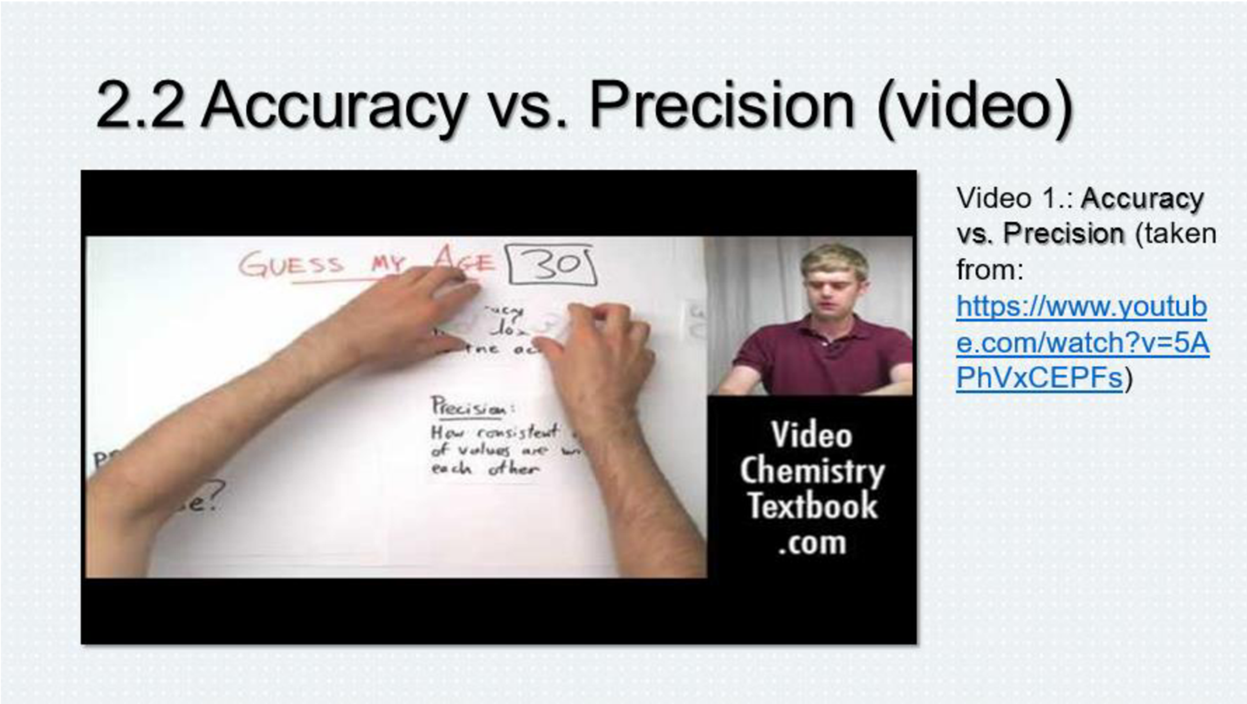

Figure 10. *1A Instrument Accuracy Verification .ppt*, slide 6

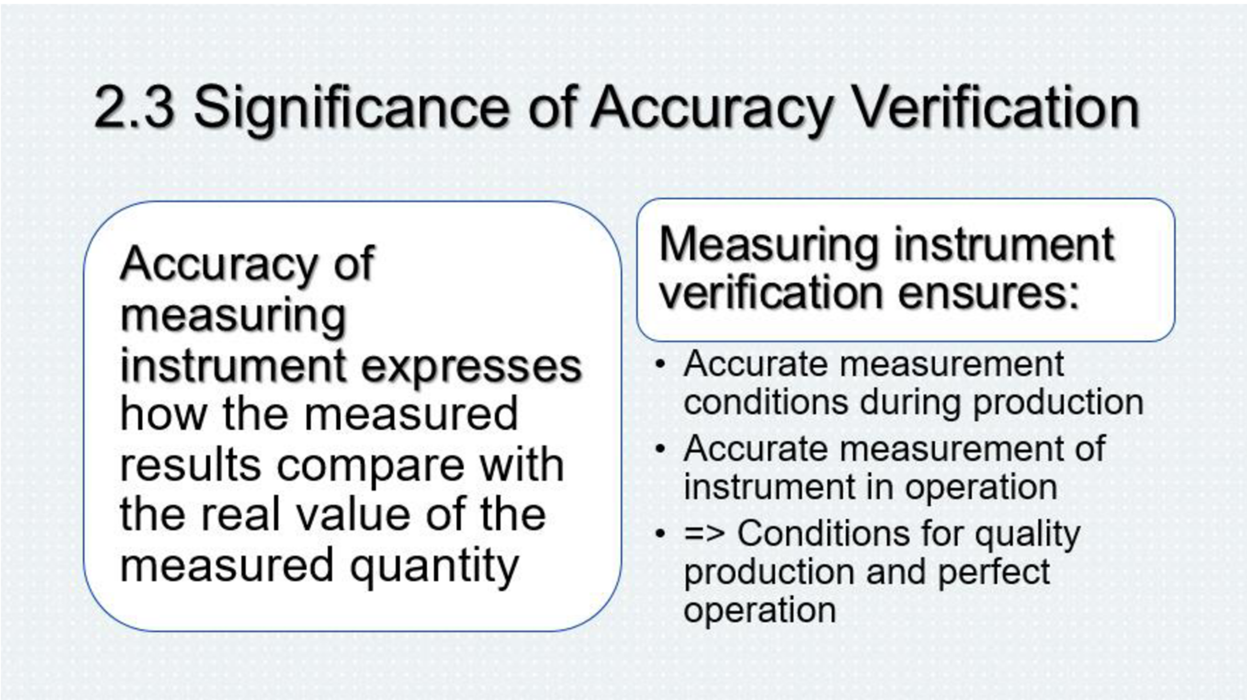

Figure 11. *1A Instrument Accuracy Verification .ppt*, slide 7

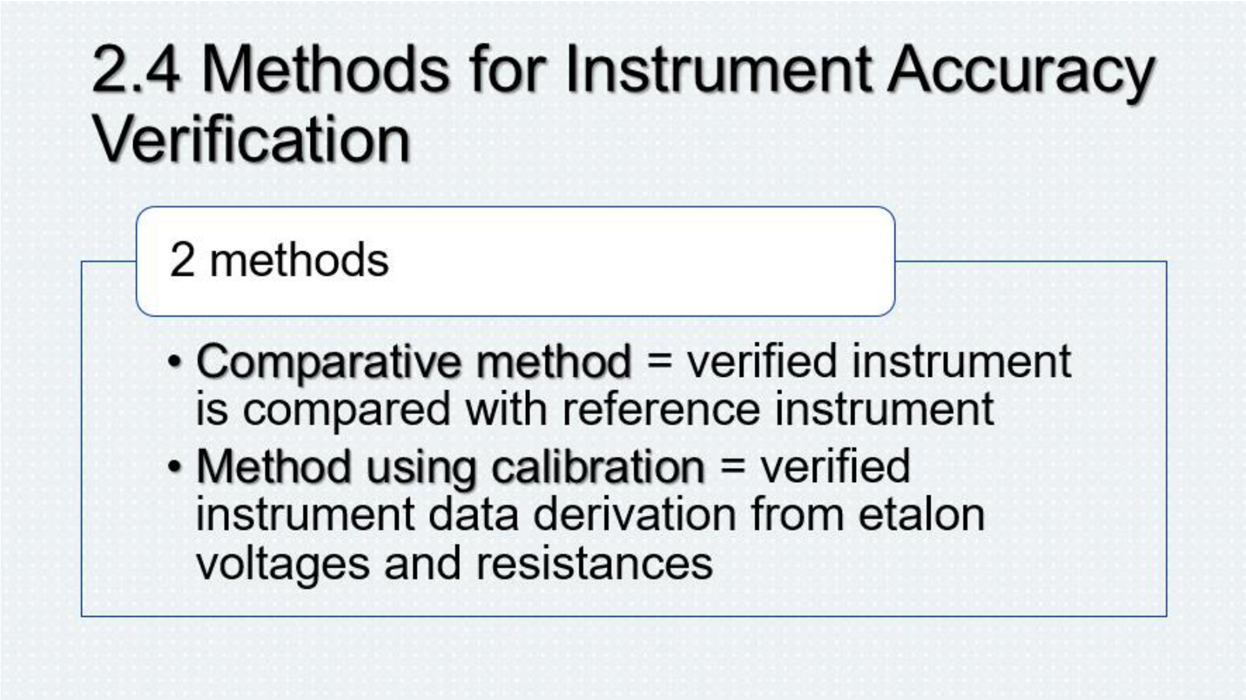

Figure 12. *1A Instrument Accuracy Verification .ppt*, slide 8

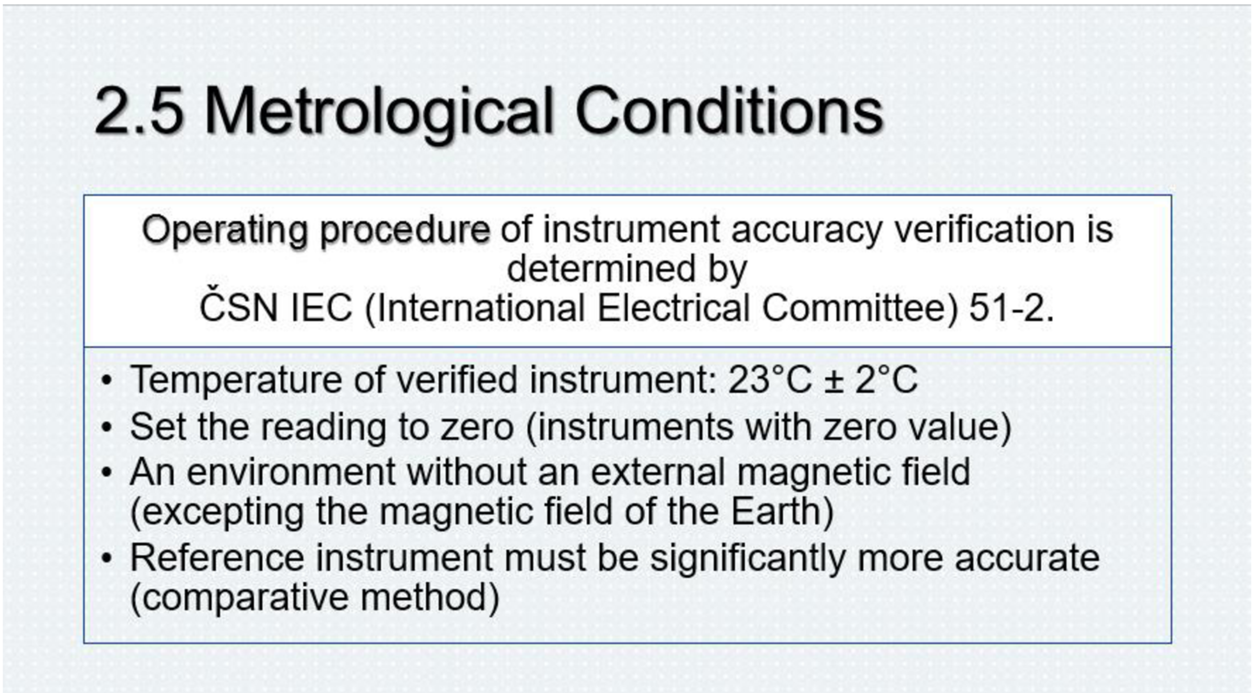

Figure 13. *1A Instrument Accuracy Verification .ppt*, slide 9

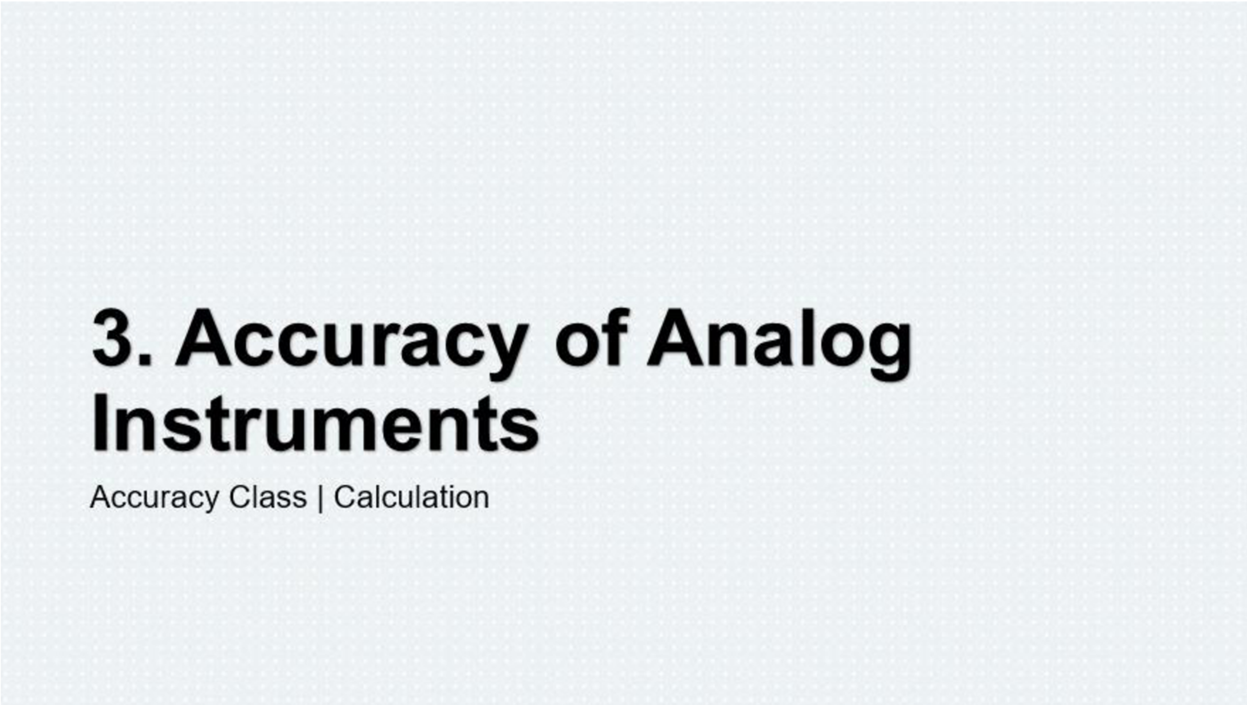

Figure 14. *1A Instrument Accuracy Verification .ppt*, slide 10

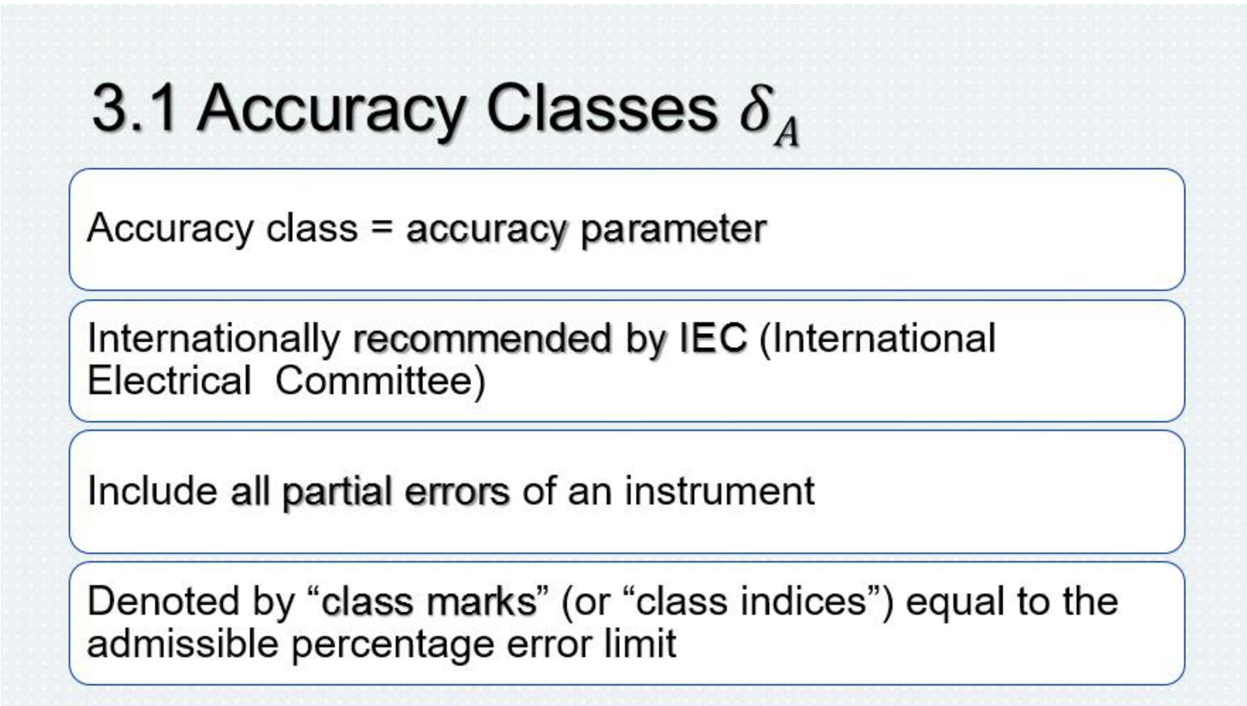

Figure 15. *1A Instrument Accuracy Verification .ppt*, slide 11

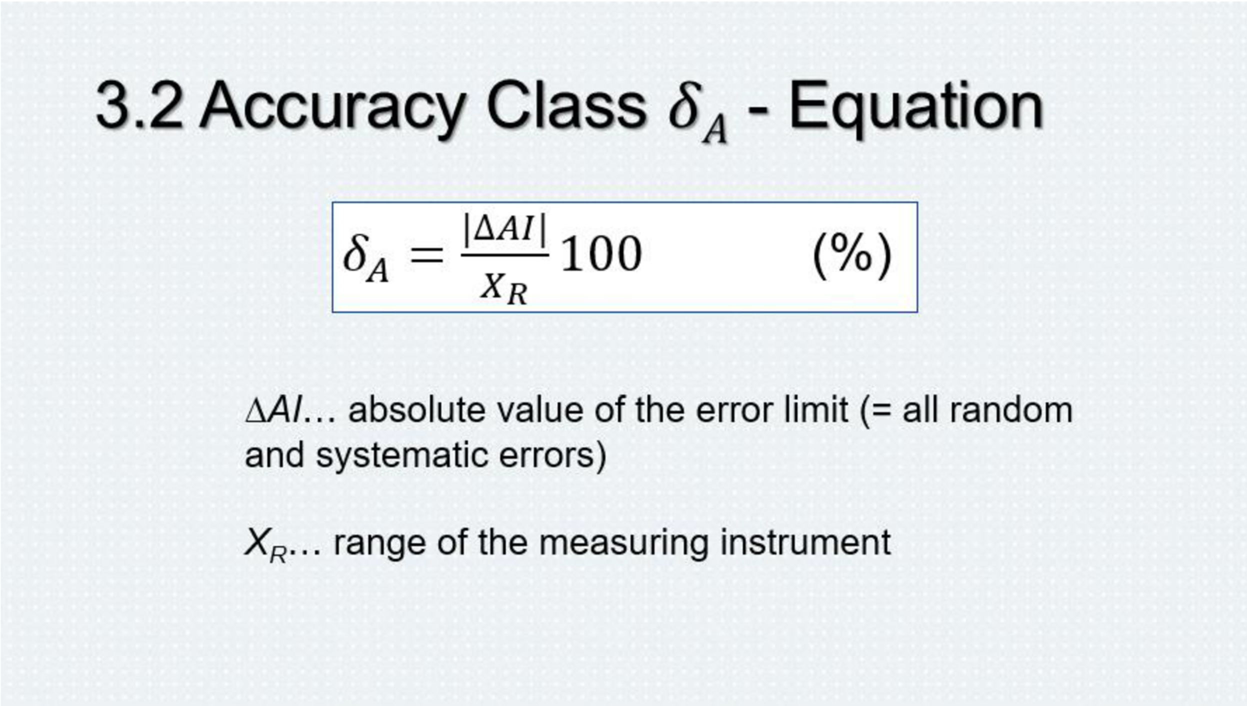

Figure 16. *1A Instrument Accuracy Verification .ppt*, slide 12

Figure 17. *1A Instrument Accuracy Verification .ppt*, slide 13

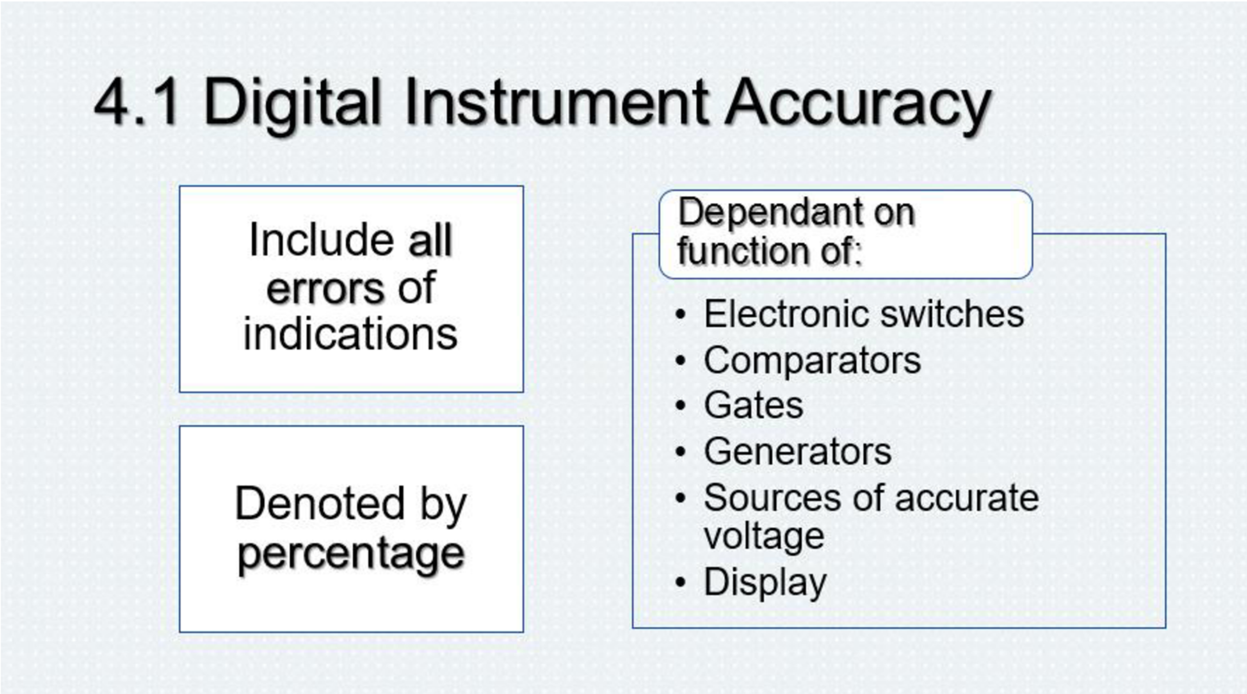

Figure 18. *1A Instrument Accuracy Verification .ppt*, slide 14

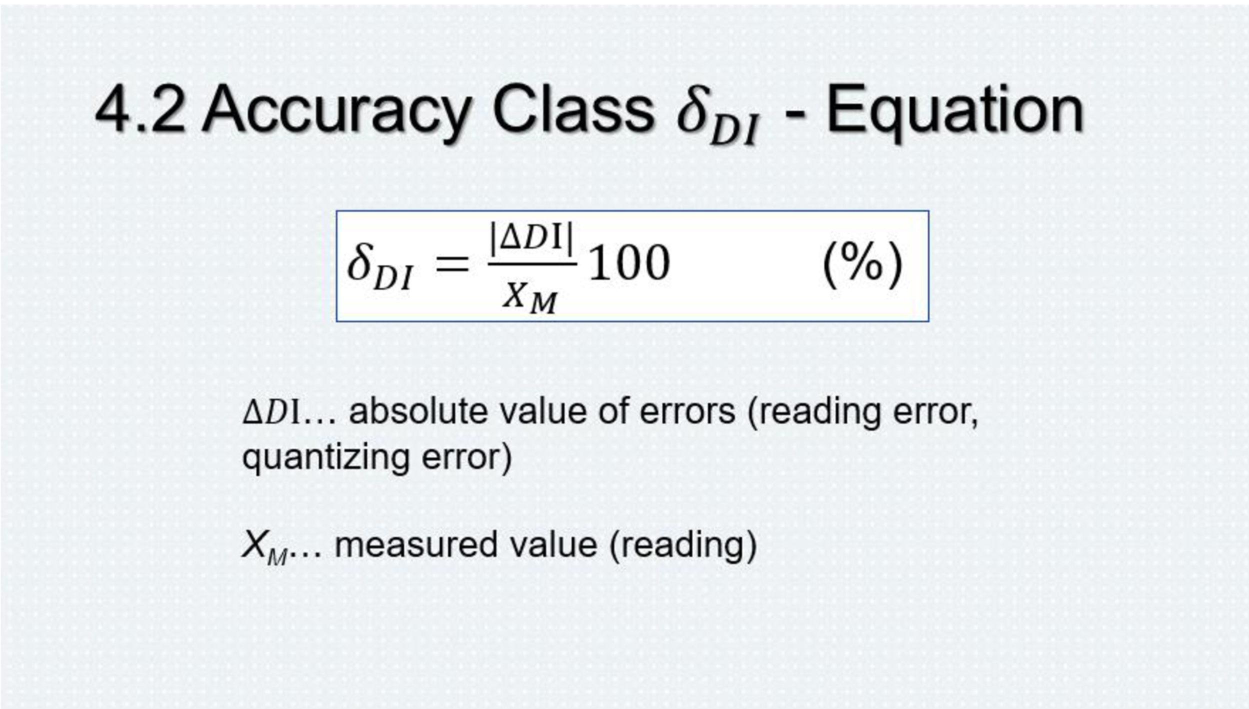

Figure 19. *1A Instrument Accuracy Verification .ppt*, slide 15

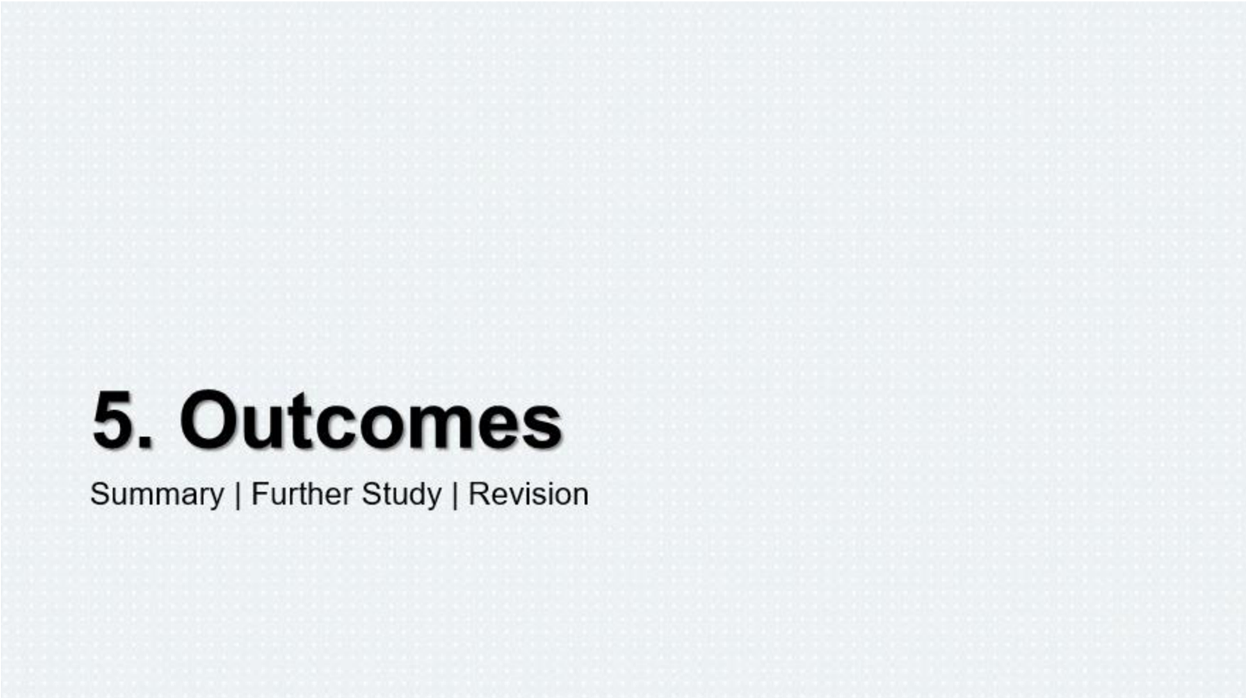

Figure 20. *1A Instrument Accuracy Verification .ppt*, slide 16

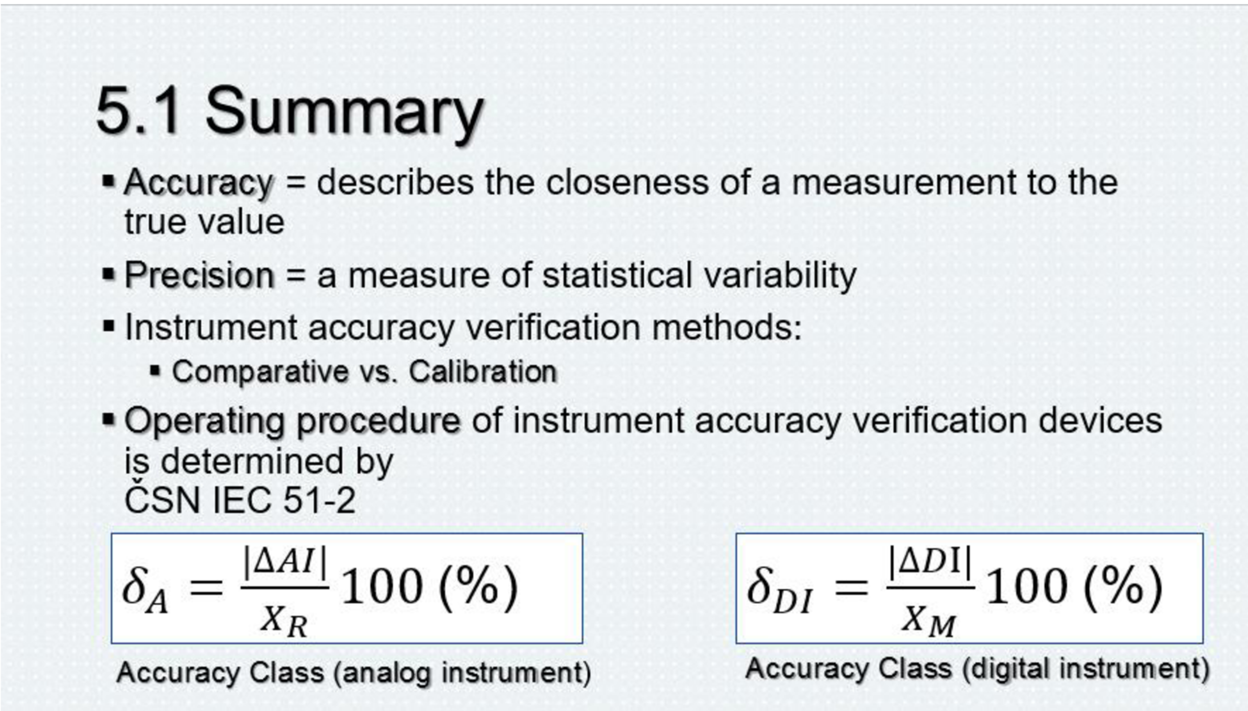

Figure 21. *1A Instrument Accuracy Verification .ppt*, slide 17

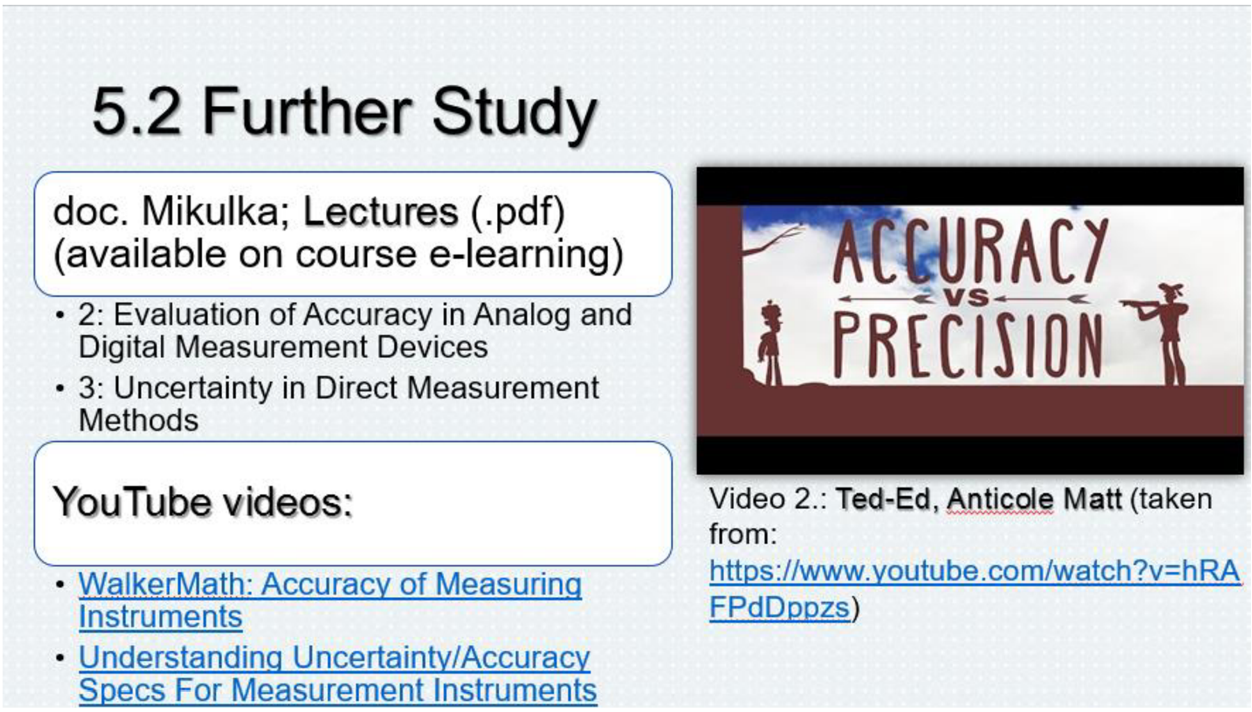

Figure 22. *1A Instrument Accuracy Verification .ppt*, slide 18

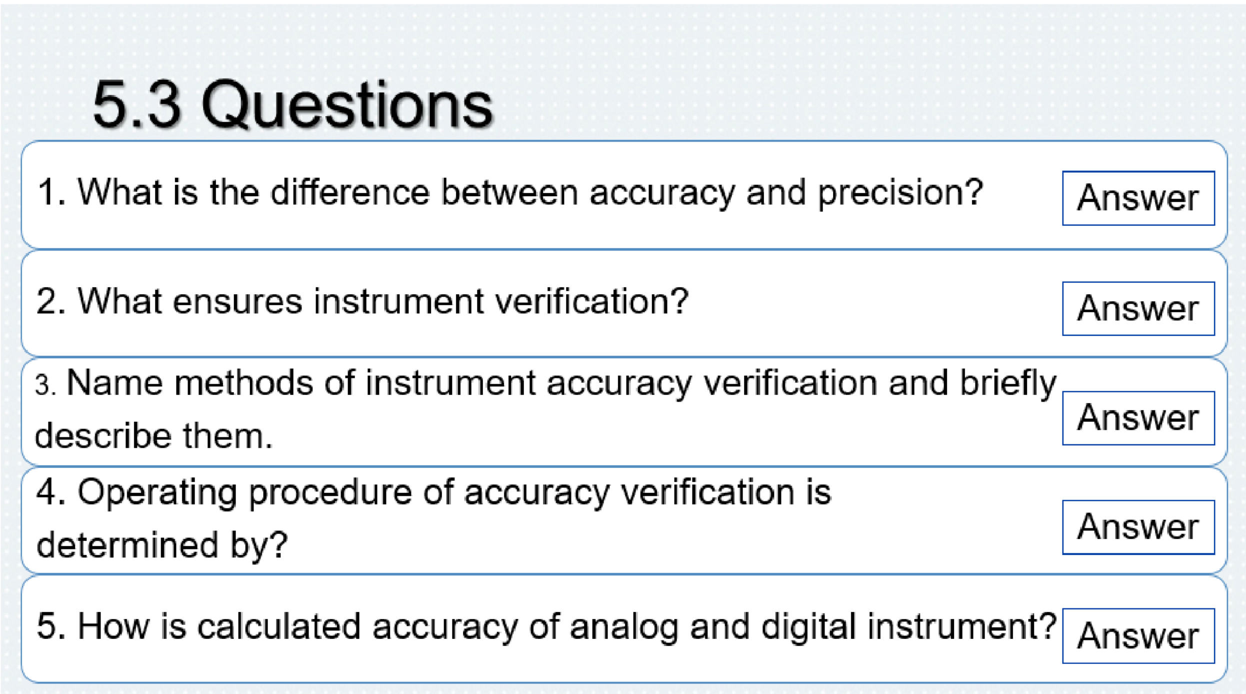

Figure 23. *1A Instrument Accuracy Verification .ppt*, slide 19

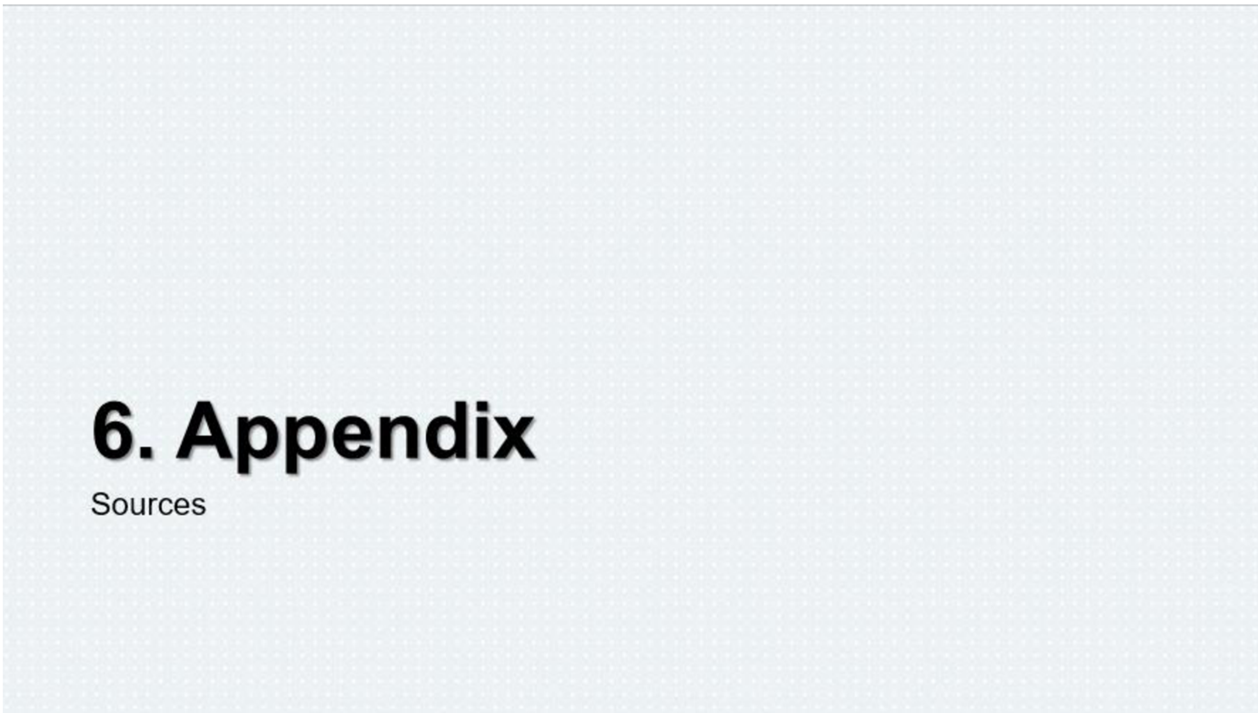

Figure 24. *1A Instrument Accuracy Verification .ppt*, slide 20

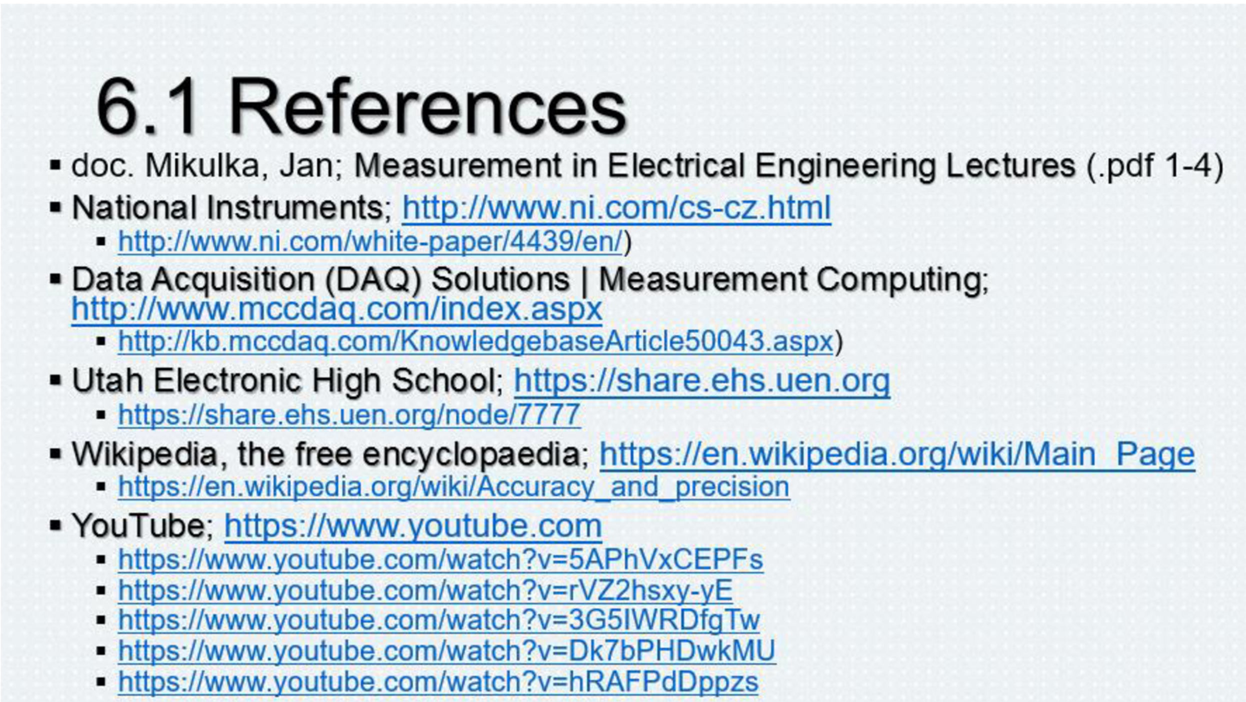

Figure 25. *1A Instrument Accuracy Verification .ppt*, slide 21

6 Worksheet Design

6.1 Annotation

Worksheet design is addressed to university students of Brno University of Technology, Faculty of Electrical Engineering and Communication. The material is to be part of subject "Measurements in Electrical Engineering". Material was not approved by any authority in the field of study (measurement in electrical engineering). The worksheet serves as an instruction to laboratory exercise and also as a laboratory elaboration of laboratory exercise, *1A Instrument Accuracy Verification*. The actual worksheet is divided into individual parts to orientate better in the worksheet.

- *Part 1* serves as a theoretical background for the laboratory exercise.
- *Part 2* is an instruction through measurement itself.
- *Part 3* describes how to process obtained values.
- *Part 5* is to present outcomes of the laboratory exercise.
- *Part 6* is revision, aiming at both theory and vocabulary.
- *Part 7* is glossary of all mentioned vocabulary, which was considered important for the worksheet.
- *Part 8* represents the key to questions and exercises which are located in the worksheet.
- *Part 9* is list of references which were used to elaborate worksheet.

The attempt of the author was to simplify and to approximate the matter to students and make them understand the significance of laboratory exercise.

(Note: Actual presentation is included on the CD attached to printed version of bachelor thesis.)

6.2 Actual Design

FACULTY OF ELECTRICAL ENGINEERING AND COMMUNICATION
department of theoretical and experimental electrical engineering

BRNO UNIVERSITY OF TECHNOLOGY	Course Name:	**MEASUREMENT IN ELECTRICAL ENGINEERING (HMVA)**	
	Student Name:		
	Year:	Study group:	
	Collaborator:	Measurement Date:	
Revised by:	Final Mark:	Mark Date:	
Task Number: **1A**	Task Name: **Instrument Accuracy Verification**		

1A INSTRUMENT ACCURACY VERIFICATION

1. AIMS

- Understand the method facilitating the accuracy verification of a measuring instrument.
- Verify the accuracy of a measuring device and learn the meaning of its measuring uncertainties.
- Learn how to properly evaluate whether a measuring device is within the limits of its accuracy class.

2. TASK

- Verify the accuracy of an analog measuring instrument on its basic scale.

Photography of the Laboratory 1A Arrangement + Description (will be attached later)

3. THEORETICAL BACKGROUND

TASK 1: Read the introduction to laboratory exercise 1A.

To verify accuracy of measuring instrument there exist two methods:

- **Comparative method**: based on comparison of verified instrument with reference instrument, which must be more accurate than verified one.
- **Method using calibration**: verified instrument data is derived from standard voltages and resistances (using calibration is complex and expensive)

The operating procedure of instrument accuracy verification is determined by *ČSN IEC 51-2.* Elementary assessments are:

- **Temperature** of verified instrument must be 23°C ± 2°C.
- Devices with expressed zero value it is necessary to **calibrate the value of zero**.
- Should your device have **more than one scale**, after verifying the progress of the basic scale, verify the rest at 100 % of given scale.
- Should an analog measuring device have more than one scale, all are to be verified as well.
- Reference instrument must be significantly more accurate than tested instrument (comparative method).

Result of the verification of instrument accuracy is **the calibration diagram**, which expresses dependency of measured value on indicated value. For accuracy purposes is more appropriate **correction curve**. Correction curve is graphically formulated dependency of correction on indicating value **C = f (X).**

CORRECTION C is value which is needed to be impute to measured value to get probably real value.

$$C = -\Delta_{X_{syst}} = X_T - \bar{X}$$ (unit of the quantity *X*) **Eq. 1**

C … correction

$\Delta_{X_{syst}}$ … systematic deviation

X_T… true value

$\bar{X}$… mean value

3.1 QUESTIONS

TASK 2: Answer following questions using The Theoretical Background 3.1

1. Name two methods for instrument accuracy verification?
2. Name at least three elementary assessments of correct operating procedure of instrument accuracy verification (*ČSN IEC 51-2*)?
3. What is the correction curve and how is correction calculated?

4. THE MEASUREMENT PROCEDURE

TASK 3: Follow measurement method and operating procedure to obtain measurement results.

4.1 MEASUREMENT METHOD

- The **comparative method** is in this laboratory exercise used for instrument accuracy verification.
- The whole measurement is **executed by computer program**, which also process results.
- **Reference measurement device is** *Agilent 34401A* (For manual go to http://www.utee.feec.vutbr.cz/files/kestazeni/pristroje/34401A.pdf)

Table 2. Accuracy of Agilent 34401A

Measured value (for the given scale)	Accuracy (% of value + % of scale)	Note
VDC (10 V)	±(0.0035 % +0.0005 %)	23°±5°C
ADC (100 mA)	±(0.050 % +0.005 %)	23°±5°C
VAC (1 – 750 V)	±(0.06 % +0.03 %)	23°±5°C, TRMS, 10 Hz - 20 kHz
AAC (1A)	±(0.1 % +0.04 %)	23°±5°C, TRMS, 10 Hz – 5 kHz

4.2 THE OPERATING PROCEDURE

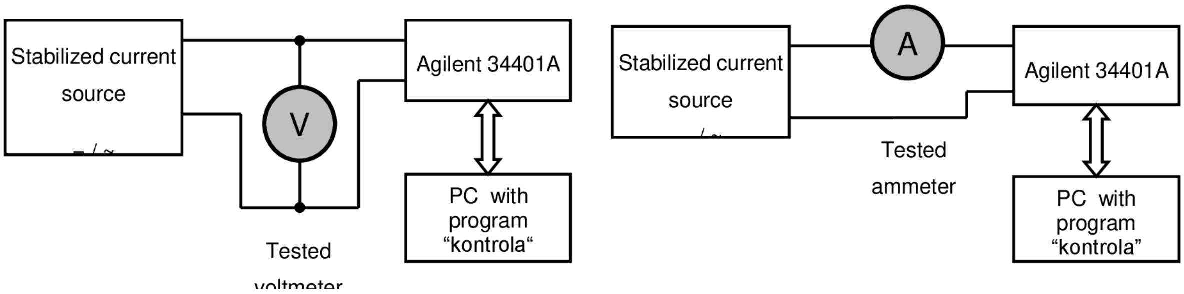

Figure 26. Diagram connection for voltmeter and ammeter verification

1. Connection of the circuit.
    a. **Connect** the circuit according to Figure 1. (choose either AC/DC voltmeter or ammeter).
    b. Disconnect the tested instrument and set the **basic scale** and calibrate the zero value.
    c. Then connect **the tested instrument again**.
2. Running measurement PC program.
    a. Run **the Excel document “kontrola.xls”** (located on the desktop).
    b. Then run **the “kontrola.vee” program**.
    c. **Enter** necessary **tested instrument data** (on the left-hand side of the program screen):
        - Accuracy class
        - Number of measurements with hysteresis (usually $n = 3$)
        - Tested scale (choose the basic scale)
        - Measuring step and tested scale, both in scale units (the tested scale must be an integral multiplication of the step)
        - Propagation coefficient (for 3 measurement there are 6 values, thus $k_S = 1.3$)
3. Running DMM Agilent 34401A.
    a. Check whether **the DMM Agilent 34401A is on.**
    b. **L**aunch the measurement by **“Start” button**.

- (**Note**: Using a potentiometer move the pointer to point towards the proper value and confirm with the computer. Setting a wrong value will result in an error. Should an error occur, there are three possible options of how to continue. The first, repeat the measurement; the second, accept the measured value; or the third, close the program.)

4. Measurement results.
   a. **Computed values and a graph** will be at your disposal (similar yet improved graph will be saved in Excel sheet *kontrola.xls*.)
   b. **Check the accuracy class** and the **scale** of the device.
   c. Modify the graph in Excel sheet *kontrola.xls* accordingly (axis, label) and print it.

- PART 3

5. PROCESSING OF RESULTS

TASK 4: Read instructions for processing obtained values and understand the significance of those values.

The final graph describes the **systematic deviations and uncertainties** as well as the **tolerance limit** for the **real values**. The final result of this exercise is a graph similar to Fig. 2. showing the progress of the systematic deviation.

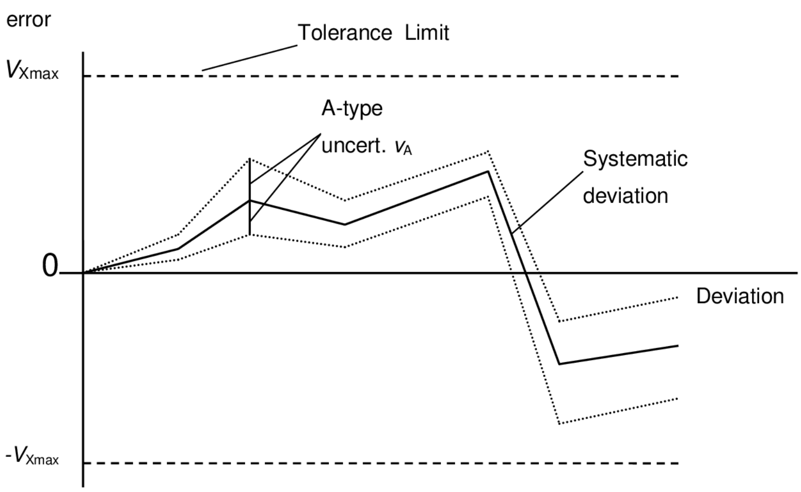

Figure 27. Progress of the systematic deviation and the A- type uncertainty

Measured values are recorded to *MS Excel* sheet:

- The first column: how many units were set; the second column gives the correct values.
- A total of 2*n* columns shows the measured values.
- The last column represents the systematic error Δ_{Xsyst} according to the Eq. 2., and the A-type uncertainty u_A according to the Eq. 5.

THE SYSTEMATIC DEVIATION $\Delta_{X_{syst}}$ can be computed for each unit of the scale using the Eq. 2.

$$\Delta_{X_{syst}} = N - \bar{X}$$ (unit of the quantity *X*) **Eq. 2**

$\bar{X}$ … the arithmetic mean of values measured by the referential instrument (these values are to be considered conventionally correct)

N… the value measured by the tested device

If THE SYSTEMATIC ERROR exceed the tolerance limit, the device is considered as deficient.

THE STANDARD UNCERTAINTY u_A is superposed on the progression of the systematic deviation.

Dashed lines highlight the accuracy tolerance limits, which can be calculated according to Eq. 3. or Eq. 4

$$u_{BX_{AMI}} = \frac{\delta_{AC} \cdot X_R}{100 \cdot \chi}$$ (unit of the quantity X) **Eq. 3**

or $$u_{BX_{DMI}} = \frac{|\delta_M X_M| + |\delta_R X_R|}{100 \cdot \chi}$$ (unit of the quantity X) **Eq. 4**

Coefficient χ = 1.

THE A-TYPE UNCERTAINTY

$$u_{AX} = k_s \cdot \sqrt{\frac{1}{m\,(m-1)} \cdot \sum_{k=1}^{m}(X_k - \bar{X})^2}$$ (unit of the quantity X) **Eq. 5**

5.1 OUTCOMES

TASK 5: Adjust values and modify graph in MS Excel sheet "*kontrola.xls*". Attach printed versions to assigned sections .

Table 3. Calculated and Adjusted Values

Attach Measured and Calculated Values

Notes:

Table 4. Systematic Error and Uncertainty Dependence on Set Value

Attach Graph

Notes:

5.2 CONCLUSION

TASK 6: Shortly describe the aim and procedure of obtaining results. Answer following questions:

Is the verified measuring instrument accurate? How do you know?

Was the measurement precise (check the standard uncertainty u_A in the graph)? Explain your estimation.

6. REVISION

6.1 QUESTIONS

TASK 7: Answer following questions.

1. What is instrument accuracy verification?
2. What does the correction curve represent? What could be observed?
3. What can cause deviations?
4. How is the standard A-type uncertainty computed? How is it connected to the total number of measurements?

6.2 VOCABULARY

TASK 8: Match terms with their definitions.

1.	accuracy class	a.	a three-terminal resistor with a sliding or rotating contact that forms an adjustable voltage divider
2.	calibration diagram	b.	an error that is not determined by chance but are introduced by an inaccuracy (as of observation or measurement)
3.	comparative method	c.	upper and lower limits to the range of particular quantity, measure etc.
4.	correction curve	d.	an instrument with the highest possible accuracy
5.	instrument accuracy verification	e.	a method based on comparison of verified instrument with reference instrument, which must be more accurate than verified one
6.	measurement uncertainty	f.	an accuracy parameter
7.	potentiometer	g.	a non-negative parameter characterizing the dispersion of the values attributed to a measured quantity
8.	reference instrument	h.	a graphically formulated dependency of correction on indicating value C = f (X)
9.	systematic error	i.	depicts the dependency of the measured value on the indicated value
10.	tolerance limits	j.	a process of measuring instrument validation

TASK 9: Fill in the English equivalence vocabulary. To find appropriate vocabulary use definitions, and previous texts from parts 1-5.

1. naměřená hodnota	=	
2. skutečná hodnota	=	
3. koeficient rozšíření	=	
4. rozsah	=	
5. ověřovaný přístroj	=	

7. GLOSSARY

	English	Definition	Czech
1.	accuracy class	an accuracy parameter	třída přesnosti
2.	analog measuring device	usually a combination of both analog machine and analog media that can together measure, record, or reproduce continuous information	analogový měřící přístroj
3.	axis	a reference line of coordinate system	osa
4.	calibration diagram	depicts the dependency of the measured value on the indicated value	kalibrační křivka
5.	calibration/gauging	a process of finding a relationship between two quantities that are unknown	kalibrace
6.	coefficient	a multiplicative factor in some term of a polynomial, a series or any expression; usually a number; does not involve any variable of expression	koeficient
7.	comparative method	a method based on comparison of verified instrument with reference instrument, which must be more accurate than verified one	srovnávací metoda
8.	correction curve	a graphically formulated dependency of correction on indicating value C = f (X)	korekční křivka
9.	deficiency	generally a lack of something	nedostatek, deficit
10.	dependency	dependence; something dependent or subordinate	závislost
11.	digital measuring device	a digital device for measuring a physical quantity	digitální měřící přístroj
12.	graph	a graphical representation of data also called a chart	graf
13.	instrument accuracy verification	a process of measuring instrument validation	ověření přesnosti měřícího přístroje
14.	label	a piece of paper or material fastened to an object that gives information about it	značka, označení

15.	measured value	a value determined by measurement	naměřená hodnota
16.	measurement uncertainty	a non-negative parameter characterizing the dispersion of the values attributed to a measured quantity	nejistota měření
17.	measuring instrument/measuring device	a device for measuring a physical quantity	měřící přístroj
18.	operating procedure/working procedure	a result of organizing tasks in the best sequence of steps to make the best use of people, equipment, tooling and materials	pracovní postup
19.	potentiometer	a three-terminal resistor with a sliding or rotating contact that forms an adjustable voltage divider	potenciometr
20.	propagation coefficient	an attenuation coefficient	koeficient rozšíření
21.	real value	an actual value	skutečná hodnota
22.	reference instrument	an instrument with the highest possible accuracy	referenční přístroj
23.	scale/range	a set of numbers, amounts, etc., used to measure or compare the level of something	rozsah
24.	systematic deviation	a systematic difference between one of a set of values and some fixed value, usually the mean of the set	systematická odchylka
25.	systematic error	an error that is not determined by chance but are introduced by an inaccuracy (as of observation or measurement)	systematická chyba
26.	tested/verified instrument	an instrument that is to be verified	ověřovaný přístroj
27.	tolerance limits	upper and lower limits to the range of particular quantity, measure etc.	mezní limity

Note: Definitions were taken from *Wikipedia, The Free Encyclopaedia* and *Macmillan Online Dictionary.*

8. KEY

TASK 2

1. *Comparative method; Method using calibration*
2. *ČSN IEC 51-2:*
   a. Temperature of verified instrument must be 23°C ± 2°C.
   b. Devices with expressed zero value it is necessary to calibrate the value of zero.
   c. Should your device have more than one scale, after verifying the progress of the basic scale, verify the rest at 100 % of given scale.
   d. Should an analog measuring device have more than one scale, all are to be verified as well.
   e. Reference instrument must be significantly more accurate than tested instrument (comparative method).
3. *Correction curve* is graphically formulated dependency of correction on indicating value C = f (X).; see *Eq. 1*

TASK 7

1. It is *a series of processes through which you test your system to verify or validate* the performance specifications published by the manufacturer of the instrument.
2. *Correction curve* is graphically expressed dependence of correction C on reading value X of measuring instrument, *C = f(X). Correction is* the value that need to be added to reading value to get real value.
3. *Cause of Deviations:*
   a. *Analog Measuring Instrument*: inaccurate mechanical setup of the measuring parts of the device, disturbing mechanical forces inside (sticking, friction), disturbing electrical and magnetic fields inside (electrical charges accumulated on parts made of insulating materials - glass window, instrument case), warming up caused by self-consumption. no calibration to the zero value on the scale, etc.
   b. *Digital Measuring Instrument*: dependant on function of electronic switches, comparators, gates, generators, sources of accurate voltage, display
4. *Standard A-type uncertainty:*
   a. $u_{AX} = k_s \cdot \sqrt{\frac{1}{m\,(m-1)} \cdot \sum_{k=1}^{m} (X_k - \bar{X})^2}$
   b. For number of measurements smaller than 10, the value is increasing by propagation coefficient k_S.

TASK 8

1.f; 2.i; 3.e; 4.h; 5.j; 6.g; 7.a; 8.d; 9.b; 10.c

TASK 9

1. *measured value*
2. *real value*
3. *propagation coefficient*
4. *scale* or *range*
5. *tested* or *verified instrument* or *device*

9. REFERENCES

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7 Conclusion

This bachelor thesis deals with several aspects of digital learning materials and additionally presents designs of two very frequent types of digital learning material, presentation and worksheet design. Based on my research and designs of digital learning material, several conclusions could be made.

Firstly, term Information Communication Technology (ICT) was introduced and described in more detail to understand the importance of constant development of new communication technology means in education process. Subsequently, the basic concept of Digital Learning Materials was established and its basic properties was described. It was suggested that, it is desirable to distinguish several forms and types of digital learning materials and use them appropriately according to the topic and the knowledge level of learners.

Secondly, the learning requirements for the subject "Measurements in Electrical Engineering" were introduced with regard to the creation of digital learning materials based on this subject. Concept of textbook, and its function as the most spread and frequent type of a didactic mean was researched. Moreover, the importance of textual and extratextual components of didactic material was emphasized. And Theory of Multiple Intelligences by Howard Gardner was introduced to be implemented into digital learning materials as much as possible.

In final part of theory background for designing digital learning materials, the design of the presentations and worksheets were mentioned, in particular their importance in the knowledge acquisition and in their overall perception, meaning the importance of outline elements (colours, font, flow, etc.).

In following practical part, the design of presentation and worksheet was realised. Both types of digital learning material were based on the laboratory exercise *1A Instrument Accuracy Verification* which is to be done in the context of subject "Measurements in Electrical Engineering". The main task was to simplify the theory as much as it would be possible and make it more understandable for learners. Also to present suitable form of laboratory exercise worksheet which would be well-arranged and would direct learners through exercise easily. Therefore, appropriate outline, more attractive for visual learners, was introduced to orientate better in the material. Another very important aspect was to follow terminology based on lectures in terms not to confuse learners.

As a result was introduced systematically arranged presentation and longer version of worksheet, both filled with activating elements (questions, exercises etc.) to introduce basic concepts of instrument accuracy and to understand the procedure of instrument accuracy verification.

The most challenging factor was the appropriateness of used outline design, level and formality of English language, and further advanced knowledge in the field of measurements in electrical engineering. Didactic scientific texts such as working procedure or necessary theory need to be very explicit and it is rather difficult to shorten them without any unambiguity.

To conclude, there exist great amount of methodology guides on how to design digital learning material for primary and secondary schools, but there is not any general guide to education materials on the university level. The procedure of designing digital learning material is very demanding and requires certain deeper knowledge and foremost experience in the field of study and practice in designing any educative material in connection to the field of the study. Consequently, designs of digital learning materials (presentation and worksheet) need to be authorized and evaluate by both experts in the field of measurements and English language and by learners whether are those suitable and could be implemented as additional study materials for the course “Measurement in Electrical Engineering”.

8 List of Figures and Tables

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