2nd INTERNATIONAL CONFERENCE

EDUCATION ACROSS BORDERS
“CRITICAL THINKING IN EDUCATION”

31 October – 1 November 2014
KORÇË

BOOK OF PAPERS

2nd International Conference Education Across Borders. “Critical Thinking in Education”

Faculty of Education                              Faculty of Education and Philology                         Faculty of Education
University of Florina                                      University of Korça                              University of Bitola

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# Table of content

**Prof. dr. Bardhyl MUSA**
The critical thinking as a learned skill .................................................................................................................. 13

**Prof. dr. Andrew Goodspeed**
"...live honorably" ............................................................................................................................................. 14

## LANGUAGE & LITERATURE

**BENITA STAVRE**

**PAVLLO CICKO**

**ANXHELA PASHKO**

**STRATEGY BASED INSTRUCTION; A TOOL TO ENHANCE CRITICAL THINKING OF LEARNERS OF ENGLISH AS A FOREIGN LANGUAGE** .......................................................................................................................... 16

**BISERA KOSTADINOVSKA**

**CREATIVE TEACHING OF ENGLISH** .................................................................................................................. 24

**BLEDAR LENJA**

**OLGER BRAME**

**IMPLEMENTATION OF STRATEGIES FOR CRITICAL THINKING IN THE TEACHING OF ALBANIAN LANGUAGE AND LITERATURE** ..................................................................................................................... 32

**DANIELA-CARMEN STOICA**

**APPLYING KEY CONCEPTS TO PSYCHOANALYTICAL AND FEMINIST CRITICISM WITHIN THE PROCESS OF READING AND TEACHING KATE CHOPIN’S THE AWAKENING. A CASE STUDY** ............................................................................................................................................ 41

**DANIELA-CARMEN STOICA**

**THE PROCESS OF INDIVIDUATION IN MAX FRISCH’S ‘HOMO FABER’ (A MYTH CRITICISM APPROACH)** ......................................................................................................................................................... 45

**ELIONA NAQO**

**MOVING STUDENTS TO CRITICAL THINKING** ......................................................................................................... 59

**ELIZABETA RALPOVSKA**

**VOCABULARY AND LANGUAGE THINKING IN ELEMENTARY EDUCATION** ........................................................................ 66

**EMINE SHABANI**

**THE ROLE OF CRITICAL THINKING AND ETHNIC, LINGUISTIC, RELIGIOUS TOLERANCE IN ALBANIAN LITERATURE** ........................................................................................................................................ 70

**ERIS RUSI**

**CRITICAL READING OF A DISSIDENT AUTHOR - “ODIN MONDVALSEN” OR THE OVERTHROW OF FALSE BELIEFS** .................................................................................................................................................. 79

**IRENA KITANOVA**

**ANALYSIS (INTERPRETATION) OF A TEXT IN CLASS TEACHING (INTERPRETATION)** .................................................. 85
JONELA SPAHO
ENCOURAGING STUDENTS’ CRITICAL THINKING IN THE INTERPRETATION OF THE ALBANIAN LITERARY WORKS OF TRADITION ................................................................. 89

LORENA ROBO (KOLE) TEACHING IDIOMS THROUGH CRITICAL THINKING IN THE ALBANIAN CONTEXT .................................................................................................. 95

LULZIM ADEMI
POSSIBILITY OF USING THE TECHNIQUES OF CRITICAL THINKING IN ALBANIAN LANGUAGE CLASSES IN THE LOWER GRADES OF PRIMARY SCHOOL IN THE FYROM ......................... 104

LULZIM ALIU
ASSESSMENT IN TEACHING AND LEARNING ALBANIAN LANGUAGE ................................................................. 110

MANJOLA TËRSHANA
THE CONTRIBUTION OF DE RADA TO THE ALBANIAN LANGUAGE ........................................................................ 117

MIGENA RIZA
THE CONCEPT OF VERB VALENCE - AN ANALOGICAL ARGUMENT BETWEEN GENERATIVISM AND THE TRADITIONAL, AS AN UNDERTAKING TOWARDS CRITICAL THINKING ...................................................................................................................... 122

NIKOLETTA TSITSANOU DIS
SPYROS GOGOLOS
ANTONIOS MALLIDIS
THE USE OF "TABOO LANGUAGE" AND MARGIN DIALECT IN THE SLOGANS OF THE "INDIGNANTS" MOVEMENT IN GREECE: A CRITICAL READING .......................................................................................................................... 127

OLGER BRAME
EDIOLA NASE
CRITICAL THINKING ISSUES IN DESIGNING OF ALBANIAN LANGUAGE TEXTBOOKS ................................................. 134

RRIOLLZA AGOLLI
THE ESSAY, AN AUTHENTIC MATERIAL THAT ENHANCES THE LEVEL OF AN INTERACTIVE TEACHING AND LEARNING .................................................................................................................. 140

SPYROS BOURAS
KOSTAS DINAS
ELENI GRIVA
‘FROM FUNCTIONAL LITERACY TO CRITICAL LITERACY’: A COMPARATIVE ACCOUNT OF THE GREEK LANGUAGE CURRICULA FOR PRIMARY EDUCATION ........................................................................ 147

SUELA KOÇA
ROBERT STRATOBÈRDHA
TEACHING ENGLISH GRAMMAR VIA DEDUCTIVE AND INDUCTIVE APPROACHES; A CASE-STUDY WITH ALBANIAN TEACHERS ......................................................................................................... 156
VIOLETA JANUŞEVA  
CRITICAL THINKING IN TEACHING MACEDONIAN LANGUAGE IN HIGHER EDUCATION .............. 166

PEDAGOGY

ADELINA HAJRULLAHU  
THE CREATIVE ACTIVITIES AT THE BEGINNING OF CLASS HOURS........................................... 174

AGIM SALLMANI  
EMIRA.. LAMA  
LEARNING METHODS AND THEIR IMPORTANCE IN TEACHING.............................................. 178

ANTONIS STRANGAS  
NIKOS KOLEDINIS  
PINELOPI PAPADOPOULOU  
PETROS KARIOTOGLOU  
EDUCATING PRE-SCHOOL STUDENT TEACHERS TO INSTRUCTIONAL DESIGN: AIMS AND ACTIVITIES .......................................................................................................................... 186

ARDITA DEVOLLI  
BEHLUL BRESTOVCI  
REWRITING SKILLS IN STUDENTS OF PRESCHOOL AND PRIMARY SCHOOL PROGRAM ............ 194

CHARALAMBOS LEMONIDIS  
STAMATINA RAPTI  
THE EFFECT OF ATTITUDES AND SELF-EFFICACY IN MATHEMATICAL PROBLEM SOLVING ...... 203

DALINA JASHARI  
CRITICAL THINKING AS A PHILOSOPHICAL VIEW IN HIGHER EDUCATION EUROPEAN AREA......................................................................................................................................... 210

DEAN ILIEV  
TATJANA ATANASOSKA  
BILJANA CVETKOVA DIMOV  
NATASHA ILIEVA  
CRITICAL RESEARCH PARADIGM IN FUNCTION OF CRITICAL THINKING IN LEARNING AND TEACHING.................................................................................................................. 213

DONIKA DARDHA  
MARIELA BURDA  
ALEKSANDRA PILURI  
THE INCLUSION OF THE PUPILS WITH EDUCATION SPECIAL NEEDS IN NORMAL CLASSES ...... 217
DORELA KAÇAUNI (KONOMI)
EDLIRA XEGA
TEACHING CRITICAL THINKING TO YOUNG ENGLISH LEARNERS IN GRADES 3 – 6. FOUR LESSON PLANS ................................................................. 227

ERINDA PAPA
VASILIKA POJANI
STIMULATING CRITICAL THINKING THROUGH READING STRATEGIES EMPLOYED BY ELT LEARNERS AT THE ADVANCED LEVEL .................................................................................................................. 239

EVIONDA PYLLI
THE ROLE OF CRITICAL THINKING IN COMMUNICATION AND INTERACTIVE TEACHING IN PRIMARY EDUCATION ................................................................................................................................. 246

FLORINA SHEHU
ASPECTS OF PLANNING THE TEACHING BASED ON CRITICAL THINKING ................................................................. 251

GEORGIOS MALANDRAKIS
ELISSAVET TANKOU
GREEK STUDENT-TEACHERS’ WILLINGNESS AND CONFIDENCE TO TEACH SUSTAINABILITY ISSUES IN PRIMARY SCHOOL .......................................................................................................................... 257

LENA DAMOVSKA
ALMA TASEVSKA
CONTEMPORARY STRATEGIES FOR THE DEVELOPMENT OF CRITICAL THINKING IN THE FIRST CYCLE OF PRIMARY EDUCATION .............................................................................................................. 264

LINDITA KAÇANI
JULIANA ÇYFEKU
A VIEW OF CLASSROOM ACTIVITIES IN SECONDARY EFL COURSE BOOKS RELATED TO THINKING SKILLS ................................................................................................................................. 273

MAGDALINI PAPAZOGLOU
NIKOLAOS CHANIOTAKIS
HOMEWORK IN THE CLASSROOM: PERCEPTIONS AND PRACTICES OF TEACHERS ......................................................................................... 279

SABIT VEJSELI
MUAMER ALA
THE CHALLENGES OF MODERN EDUCATION ................................................................................................................................. 286

VASILIKA POJANI
ERINDA PAPA
DONIKA DARDHA
STUDENTS AND TEACHERS’ PERCEPTIONS OF EFL LEARNING AND TEACHING STYLE. A case study of EFL Albanian students and teachers at “Fan S. Noli” University of Korça ........................................................................... 293
PSYCHOLOGY

ANASTASIA ALEVRIADOU
CHOICE AS AN ASPECT OF CRITICAL THINKING FOR STUDENTS WITH INTELLECTUAL DISABILITIES................................................................. 302

ARJAN KAMBURI
ILIA BELLO
THE DEVELOPMENT OF CRITICAL THOUGHT TO STUDENTS WITH LEARNING DIFFICULTIES........................................................................................................... 308

BUJANË TOPALLI
USAGE OF SOCIAL MEDIA AND CRITICAL THINKING......................................................................................................................... 314

DIMITRIOS PNEVMATIKOS
ATHINA KARAMANIDOU
THE EFFECT OF THE INTUITIVE BELIEF BIAS ON SOLVING DEDUCTIVE SYLLOGISMS: A DEVELOPMENTAL APPROACH ................................................................................................. 317

ELDA PANARITI (NUNI)
EDA STASA
ROLANDI LALAJ
ÇILJETA SIMAKU
CRITICAL THINKING IN DEPRESSION AND ANXIETY DISORDERS: DISTINCTIVE AND OVERLAPPING FEATURES ................................................................................................................. 325

LORENA PRIFTI
ATTACHMENT TYPES AND THE IMPORTANCE THROUGHOUT THE LIFE CYCLE................................................................. 332

MARIETA PETROVA
ENRICHING THE BRAIN AND CRITICAL THINKING IN EDUCATION ......................................................................................................................... 339

SHQIPE KUKAJ
ARDITA DEVOLLI
IDENTIFICATION AND TREATMENT OF CHILDREN WITH SPEECH AND LANGUAGE DISORDERS................................................................................................................................. 343

SCIENCE, MATH., ICT

ADELINA NICOLETA GALICA
THE IMPORTANCE OF TEACHING CRITICAL THINKING TO NURSE STUDENTS................................................................. 351

ANDRIKOU ASIMINA
DARATZI PASXALIA
‘YOUNG SCIENTISS’ IN THE AREA OF FLORINA: A BOARD GAME OF ELECTRICITY, MIXTURES AND LOCAL HISTORY ..................................................................................................................................................................................... 357
ANTONIA KARAGIANNIDOU
ANNA SPYRTOU

SCIENCE-TECHNOLOGY-SOCIETY-ENVIRONMENT APPROACH: PROMOTING CRITICAL THINKING TO PRIMARY STUDENT TEACHERS BY DEVELOPING OUT-OF-SCHOOL ACTIVITIES ............................................................................................................................................... 362

ARTO ADILI
LORENA MARGO
ELJONA MILO

MATHEMATICAL GAMES WITH LETTERS OF ALBANIAN AND GREEK LANGUAGES......................... 369

ATHINA K. TESTEMPASSI
TIMOLEON ANTONELIS

SCIENCE AND TECHNOLOGY EDUCATION. TEACHERS’ PERCEPTIONS FOR TEACHING SCIENCE AND TECHNOLOGY ....................................................................................................................................... 378

BLENDI BAZE
ANXHELA FRASHËRI

STUDENTS' EVALUATION, A CHALLENGE BETWEEN OBJECTIVITY AND SUBJECTIVITY ............. 386

CATHERINE DIMITRIADOU
ANNA SPYRTOU

IN-SERVICE PRIMARY TEACHERS' VIEWS AND PRACTICES FOR PROMOTING INNOVATIVE TEACHING-LEARNING ENVIRONMENTS ABOUT SCIENCE ........................................................................................................... 391

GEORGIOS MALANDRAKIS
AIKATERINI GKIGKOPOULOU
ANASTASIOS ZOUPIDIS

IN-SERVICE SECONDARY TEACHERS' IDEAS AND PRACTICES ABOUT TEACHING AND LEARNING IN SCIENCE EDUCATION ......................................................................................................................... 399

SOFIA AVGITIDOU
PENELope PAPADOPOULou

VASILIKI ALEXIOU

TEACHERS’ BELIEFS AND PRACTICES REGARDING SCIENCE TEACHING AND LEARNING IN EARLY CHILDHOOD EDUCATION .......................................................................................................................... 408

P. KARIOTOGLOU
D. PNEVMATIKOS
M. KARNEZOU

IN-SERVICE TEACHERS’ PROFESSIONAL DEVELOPMENT ON SCIENCE EDUCATION: DESIGNING PRINCIPLES OF A RESEARCH PROJECT ....................................................................................................................... 416
EDA STASA
ELDA PANARITI (NUNI)
CRITICAL THINKING APPLIED IN NURSING ................................................................. 424

IOANNIS TRIKKLIOTIS
DIMITRIOS PNEVMATIKOS
TEACHERS’ BELIEFS FOR THE EMOTIONS EXPERIENCED BY CHILDREN IN THEIR CLASS ........ 432

MARIA-RAFAELA TZIOUVARA
AN INQUIRY APPROACH FOR TEACHING SOUND IN PRIMARY SCHOOL EMPLOYING EDUCATIONAL ROBOTICS CONSTRUCTION TECHNOLOGY ........................................ 440

MARSEL KOTORI
MEASURING SOURCE DIVERSITY IN WSN ........................................................................ 449

MARZANNA SEWERNY-KUZMANOVSKA
TATJANA ATANASOVA –PACHEMSKA
SONIA CHALAMANI
PROBLEM SOLVING SCIENTIFIC MODES USED WHEN DOING WORD PROBLEMS .................. 454

PANAGIOTA ZACHOU
ANNA SPYRTOU
SETTING A FESTIVAL ENVIRONMENT FOR PROMOTING CRITICAL THINKING IN PRIMARY SCIENCE EDUCATION ......................................................................................... 459

STERGIOS GKITSAS
FOUR SEASONS PHENOMENON: DESIGN AND DEVELOPMENT OF A ‘SCIENTIFIC KIT BY PRIMARY STUDENTS ......................................................................................... 466

SHKELQIM KUKA
TEUTA MYFTIU
A VIEW ON SOME MICROSOFT EXCEL ADD-INS AT LINEAR ALGEBRA ................................ 473

SNEZANA JOVANOVA-MITKOVSKA
HOW PRESCHOOL CHILDREN LEARN MATH? .................................................................... 477

SOUDI ANTONIA
‘ELECTRICIANS’ GAME: ELECTRICITY CORNER CONSTRUCTION THROUGH A SCIENCE PROJECT IN A FOREIGN LANGUAGE ........................................................................ 487

THOMA LICE
ARDIAN MATKA
PHYSICS INTERACTION WITH DIALECTICAL MATERIALISM ........................................... 492
VALENTINA GULEVSKA
THE EFFECTS OF "INFORMATION REVOLUTION" UPON THE CRITICAL THINKING AND VALUES IN EDUCATION ................................................................. 497

VASILEIOS SOTIROUDAS
MARKOS KOUNDOUROS
IOANNIS GARITSIS
RAISING PARENTS' AWARENESS TO DEVELOP A MORE CRITICAL ATTITUDE TOWARDS THE APPLICATIONS CONCERNING INTERNET COMMUNICATION. A CASE STUDY .................. 502

VASILOUDI ANGELIKI
KOTABASIS GEORGIOS
DESIGN AND DEVELOPMENT ‘SCIENTIFIC’ KITS BY PRIMARY STUDENTS FOR PARTICIPATING IN SCIENCE FESTIVAL: THE CASE OF A TRAIN KIT .................. 507

VLADIMIR TALEVSKI
MUSIC IN THE INCLUSIVE EDUCATION PROCESS ................................................................. 512

SOCIAL SCIENCES

ATHANASE GOTOVOS
GREEK-ALBANIAN COOPERATION FOR THE ESTABLISHMENT OF A NEW APPROACH IN HISTORY TEACHING ........................................................................................................... 518

BUJAR SAITI
SOME ATTITUDES AND OPINIONS OF STUDENTS OF FACULTY OF PEDAGOGY IN SKOPJE OF THE WORK OF CLASS TEACHERS ON THE SUBJECT OF PHYSICAL EDUCATION GAINED DURING THEIR PRACTICE IN SCHOOLS ........................................................................................................... 522

EDIT LEZHA
THE ROLE OF CRITICAL THINKING STRATEGIES IN SCHOOL PRINCIPAL’S JOB STRAINS MANAGEMENT ........................................................................................................... 526

ERMIRA JASHIKU
CRITICAL THINKING AND THE USE OF VISUAL TOOLS IN THE DISCIPLINE OF GEOGRAPHY TEACHING ........................................................................................................... 530

EVANGELIA - ZOI BARA
SUSTAINABILITY OF LOCAL COMMUNITIES: DESIGN AND DEVELOPMENT A ‘SCIENTIFIC’ KIT FOR PRIMARY STUDENTS ........................................................................................................... 534

GJERGI PENDAVINJI
THE NEED FOR DIDACTICS OF PHILOSOPHY ........................................................................................................... 540

KONSTANTINOS NIKOLANTONAKIS
TEACHING AND LEARNING UNDER THE PRISM OF THE SYSTEMIC APPROACH: QUESTIONS FOR THE DEVELOPMENT OF CRITICAL THINKING ........................................................................................................... 546
KOSTAS KASVIKIS
WHO’S AFRAID OF CRITICAL THINKING IN HISTORY?: THE CASE OF GREEK PRIMARY EDUCATION.......................................................... 552

MALCEV MARJAN
BASIC PARAMETERS FOR THE DEVELOPMENT OF MOBILITY IN RUNNING DISCIPLINES IN THE PHYSICAL EDUCATION CLASSES .......................................................... 560

MARIJANA DIMITROVA KROTEVA
THE EFFICIENCY OF LEARNING ENGLISH LANGUAGE THROUGH PAINTING .......................................................... 564

MAYA RAUNIK KIRKOV
CRITICAL THINKING SKILLS IN VISUAL ART EDUCATION .......................................................... 568

MYJESER ILJAZI
SONGS AND TRADITIONS OF EMINENT .......................................................................................... 574

NIKOLAS SOUTOPOULOS
DION TUSHI
ERIKETA KOÇOLLARI

PANAGIOTIS PAPAKONSTANTINOU
INTERCULTURALISM-MULTICULTURALISM: CRITICAL REVIEW OF THE EDUCATIONAL REALITY IN THE GREEK EXAMPLE .......................................................... 587

VENETIA KATSIFI
CRITICAL THINKING IN EDUCATION: THE CONTRIBUTION OF THE TEACHING OF HISTORY .......................................................................................... 592
PROBLEM SOLVING SCIENTIFIC MODES USED WHEN DOING WORD PROBLEMS

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Abstract
The negative attitude towards Mathematics may present an obstacle in students’ learning and may limit their potentials. Many students become discouraged when they hear that the Natural Sciences entail knowledge of mathematics. Although the teacher and some more gifted students find the word problems easy, most students do not feel so. Instead, they develop aversion to the word problems regardless of the fact that they are essential in solving scientific problems. Word problems solving is a complex task which entails the integration of many concepts, facts and methods. Unlike to arithmetic problems presented with standardized symbols and requiring specific algorithms application, word problems are very diverse and can often be solved in several ways. Translation of word problems into math symbols is one of the most difficult parts in word problems solving, but also the most important one. Without it, math would be impossible to apply with real problems solving. This paper presents several methods for solving word problems which contribute to the development of critical thinking with students.

Key words: scientific skills, word problems, translation/interpretation, natural language, mathematical symbols

Introduction
The negative attitude towards Mathematics may present an obstacle in students’ learning and may limit their potentials. Many students get discouraged when they hear that the natural sciences demand knowledge in mathematics.

Even though the teacher and some more gifted students find the word problems easy, most students do not feel so. Unfortunately, aversion is being developed with students towards the word problems the command of which is essential in solving scientific problems. In practice, the problems do not show up in the form of arithmetical equations. In order to be solved they must be translated from a natural language into mathematical symbols.

Solving word problems is a complex task which demands integration of a large number of concepts, facts, and methods. Unlike to arithmetic problems presented with standardized symbols and requiring specific algorithms application, word problems are very diverse and can often be solved in several ways.

Translation of word problems into math symbols is one of the most difficult parts in word problems solving, but also the most important one. Without it, math would be impossible to apply with real problems solving.

In the natural language, students firstly learn how to recognize words, then phrases, and finally the sentences. A similar approach is applied in solving word problems. The students firstly learn the vocabulary, and after that they go onto the phrases and sentences.
Translating words into mathematical symbols

One of the greatest challenges in solving word problems is translating them into symbols. In table 1.1 words that refer to specific mathematical operations are presented.

**Table 1.1** Word problems terminology for specific mathematical operations

<table>
<thead>
<tr>
<th>+</th>
<th>-</th>
<th>.</th>
<th>:</th>
<th>xy</th>
<th>?</th>
<th>=</th>
<th>( )</th>
</tr>
</thead>
<tbody>
<tr>
<td>adds</td>
<td>change</td>
<td>by</td>
<td>divides</td>
<td>cubed</td>
<td>how much?</td>
<td>is</td>
<td>all</td>
</tr>
<tr>
<td>and</td>
<td>decreased</td>
<td>double</td>
<td>cuts</td>
<td></td>
<td>how far?</td>
<td>are</td>
<td>grouped</td>
</tr>
<tr>
<td>plus</td>
<td>difference</td>
<td>times</td>
<td>percent</td>
<td>exponent</td>
<td>what?</td>
<td>matches</td>
<td>quantity</td>
</tr>
<tr>
<td>sum</td>
<td>less</td>
<td>multiples</td>
<td>quotient</td>
<td>at a degree</td>
<td>when?</td>
<td>is equal to</td>
<td>taken together</td>
</tr>
<tr>
<td>together</td>
<td>minus</td>
<td>from</td>
<td>relation</td>
<td>divide by reciprocal</td>
<td>what value?</td>
<td>was</td>
<td>was</td>
</tr>
<tr>
<td>total</td>
<td>subtracts</td>
<td>product</td>
<td>value</td>
<td>a third of</td>
<td>squared root</td>
<td>will be</td>
<td>will be</td>
</tr>
<tr>
<td>addition</td>
<td>extracts</td>
<td>of</td>
<td></td>
<td>a part</td>
<td>(x0,5) squared</td>
<td>makes</td>
<td>makes</td>
</tr>
<tr>
<td>with</td>
<td>takes out</td>
<td></td>
<td></td>
<td></td>
<td>(x2)</td>
<td>gives</td>
<td>gives</td>
</tr>
<tr>
<td>more</td>
<td>owes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>increased by</td>
<td>decreases</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>by</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

We always have to see the context in interpretation of word problems, because there is not always a linear relationship between words and symbols. In the next exercise, the words are used in their most general meaning. Figure 1.1 presents how the Pythagorean Theorem can be translated from a natural language into symbols. Presentation in symbols is much simpler than presentation in a natural language.

**Exercise 1.1 Translating the words into mathematical symbols**

In the list that follows, words that are common in word problems are shown. Translate the most common mathematical meaning of each of the following words and mark it with an appropriate symbol: addition (+), subtraction (-), division (:), exponentiation (x^y), unknown (?), even (=) or parentheses ( ).

| adds | decreases | how much? | part | extracts | same as |
| all  | separated | total     | to   | reciprocal | third of |
| likewise | difference of double | increased for what? | plus | value | triple |
| addition | divides | less | degree | repeats | was |
| equal to | equal exponent times | more | product of squared | divides | what? |
| matches | divides minus multiplies | minus | quarter of quotient | decreased for squared root | will be |
| are | divides | cubes | divided | subtracts | when? |
| by | decreases percent of | to group | of | sum | with |
| cubed | half of | half of | | together | gives |
| owes | | half of | | | is |

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In every right triangle the square of the hypotenuse is equal to the sum of the squares in the cathetus
\[ c^2 = a^2 + b^2 \]

**Picture 1.1 Translating the Pythagorean Theorem from a natural language into mathematical symbols**

Translating the natural language into algebraic expressions
Arithmetic is a main branch in mathematics, and the algebra is a tool for presenting arithmetics in a general form.

The algebra is an irreplaceable tool for solving word problems, and even though the algebraic equations are more simple expressions in the natural language, the process of translating from the natural language into algebraic expressions is not that simple.

Figure 2.1 shows how a natural language can be translated into mathematical symbols. The equation is much simpler. To be successful in solving tasks, students must learn how to translate the textual descriptions into algebraic expressions.

\[ E = mc^2 \]

**Picture 2.1 Translating a sentence into a relativity equation**

The following exercise is designed for practicing translation of phrases into algebraic expressions. Students will learn to solve the problems better as they master the translation of phrases into algebraic expressions.

**Exercise 2.1 Matching phrases of natural language with algebraic expressions**

Read the phrase on the left and match it with the appropriate expression on the right.
The first phrase is solved for an example.

<table>
<thead>
<tr>
<th>Natural language</th>
<th>Algebraic expression</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Sum of two and unknown x</td>
<td>d1 – d2</td>
</tr>
<tr>
<td>2. Reciprocal value of the temperature</td>
<td>s : t</td>
</tr>
<tr>
<td>3. Distance difference</td>
<td>x6</td>
</tr>
<tr>
<td>4. A relation between path and time</td>
<td>3h</td>
</tr>
<tr>
<td>5. The sum of lengths decreased by 5</td>
<td>m / 2</td>
</tr>
<tr>
<td>6. A square root of the difference a-b</td>
<td>1 / T</td>
</tr>
<tr>
<td>7. Height by factor 3</td>
<td>(d1 + d2) – 5</td>
</tr>
<tr>
<td>8. The product of two lengths squared</td>
<td>( a - b )</td>
</tr>
<tr>
<td>9. Degree higher from x3</td>
<td>(11 - 12)2</td>
</tr>
<tr>
<td>10. Half of the mass</td>
<td>2 + x</td>
</tr>
</tbody>
</table>

**Exercise 2.2 Formulating phrases of algebraic expressions from a natural language**

Figure 2.1 shows how an algebraic expression can be formulated from a description of
a natural language. Formulate the algebraic expressions for each of the following definitions. See table 1.1 to see the correlation between the terms and the mathematical operations.

1. The perimeter of the circle \((L)\) with radius \(r\) is equal to the product of its diameter \((2r)\) and the number \(\pi\).
2. The area trapezoid \((P)\) is a product of the half-sum of its bases \((a, b)\) and the height \((h)\).
3. The area of the rhombus \((P)\) with diagonals \(d_1\) and \(d_2\) is equal to half the product of the diagonals.
4. The pressure \((P)\) is a relation between the force \((F)\) and the area \((S)\).
5. The product of the sum and the difference of both expressions \((A, B)\) is equal to the difference of its squares.
6. The force \((F)\) is equal to the product of the mass of the body \((m)\) and its acceleration \((a)\).
7. Work \((W)\) is a product of the force \((F)\) and the distance \((d)\) on which the force has effect.
8. Density \((\rho)\) is the relation between the mass \((m)\) and the volume \((V)\).
9. The area of the square \((P)\) is equal to the length of the square’s side \((a)\).
10. The current \((I)\) is proportionate to the voltage \((U)\), but is inversely proportionate to the resistance \((R)\).

Translating algebraic expressions in natural language

It is sad to say that many of the students see the equations in textbooks as they were hieroglyphs. Luckily, they can learn to interpret them. All equations which are given below are algebraic expressions which include addition, subtraction, multiplication, division, exponentiation, or nth root. The problem is that the names of the variables are not \(a, b, c\) or \(x, y, z\), which are most commonly met in the mathematics textbooks. Even though the symbols are different, the principles and operations are the same. Science requires that concepts expressed in a natural language be translated into algebraic expressions whereas those expressed in algebraic expressions be translated into a natural language. The following exercise focuses on the second skill: translating algebraic expressions into a natural language.

Exercise 3.1 Formulating phrases of algebraic expressions from a natural language

This following exercise is designed for training translation of algebraic equations in a natural language. Two expressions are given for each equation; one is correct, and the other one is incorrect. Explain the algebraic expressions and circle the correct expressions.

| 1. \( G = mg \)  | (a) As the mass increases, the weight decreases.  
(b) The weight of the body is a product of the mass and Earth’s acceleration. |
|------------------|---------------------------------------------------------------|
| 2. \( E = mc^2 \) | (a) A small amount of material presents a large amount of energy.  
(b) As the mass increases, the energy decreases. |
| \( P = \frac{ah}{2} \) | (a) The area of the triangle is proportionate to the height.  
(b) The area of the triangle is inversely proportionate to the basis. |
| \( a^m \cdot a^n = a^{m+n} \) | (a) The product of degrees with equal bases is a degree with the same basis, and an index equal to the sum of the indexes of the multiplier.  
(b) The product of degrees with equal bases is a degree with the same basis, and an index equal to the product of the indexes of the multiplier. |

2nd EduCbr-CTE 2014, Albania-Korçë. 457
5. $V = \frac{3}{4}\pi r^3$  
(a) If the radius of the ball increases 2 times, the volume will increase 8 times. 
(b) The volume of the ball is the sum of $\frac{3}{4}$ and the product of $\pi$ and the radius cubed.

6. $\rho = \frac{m}{V}$  
(a) The density does not depend on the volume and the mass. 
(b) The density is the relation between the mass and the volume.

7. $P = ah$  
(a) The area of the rhombus is proportionate to the height. 
(b) The area of the rhombus is the relation between the basis and the height.

8. $\sin \alpha = \frac{a}{c}$  
(a) Sine of an acute angle in a right triangle is a relation of the opposite cathetus of the angle and the hypotenuse. 
(b) Sine of an acute angle in a right triangle does not depend on the hypotenuse.

9. $P = \pi r^2$  
(a) The area of the circle is inversely proportionate to the radius. 
(b) If the radius of the circle increases 3 times, the area will increase 9 times.

10. $T = \frac{1}{\sqrt{g}}$  
(a) The period of the pendulum does not depend on the mass of the pendulum. 
(b) As the length is increased, the period of the pendulum is decreased.

REFERENCES