Using Knowledge of Basic Mathematics to Increase Technical English Literacy

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Abstract

The following paper aims to demonstrate how ESP teachers can employ basic Mathematical concepts to maximize technical comprehension and concept development during engineering classes. Moreover, the paper proposes an integrated skills approach model of how Geometry lessons can expand abstract thinking and increase technical comprehension level by means of selected activities that develop gradually and recycle vocabulary, provide feedback and help students corroborate mathematical understanding with English comprehension. The paper seeks to provide a practical approach to the way in which English teachers can harness students' knowledge of basic mathematics to increase their technical English literacy by transferring and expanding concepts to render technical English output.

Keywords: *Basic Mathematics, knowledge transfer, metacognition, strategic behavior, technical literacy*

Introduction

The area of English literacy includes the six aspects of reading, writing, listening, talking, viewing, and making visual representations (Altieri, 2010; Tompkins, 2009). When it comes to ESP courses, particularly technical English, the same set of skills is developed with a selection of input from the technical field. The learning outcomes of developing technical literacy are the students' capacity to comprehend and react to engineering-based input. In developing technical English skills, educators ought to stimulate the development of specific (i.e. technical) literacy by integrating knowledge and skills students have from another subject area into their language instruction, i.e. mathematical concepts that students have developed over the years. Consequently, every time students transfer learning from one area into the other, they display „the ability to appropriately apply information and skills learned in one setting to a similar or different setting" (Thomas, 2007, p. 5). Since most

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technical students are already averagely competent at Mathematics, the transfer of concepts should be smooth as they rely heavily on familiarity that boosts confidence. Moreover, the thinking processes they used to learn basic Mathematics coupled with increased awareness of how the technical field relates to Mathematics provides them with the necessary tools to operate effectively in their chosen field of professional activity.

Despite the fact that some researchers point out the striking difference between Mathematics and literacy with little overlap in skills and concepts (Altieri, 2010; Fogelberg et al., 2008), other researchers have emphasized that countless connections that exist between the two areas. For instance, Devlin (2000, p. 262) points out that „mathematicians think about mathematical objects and the mathematical relationships between them using the same mental faculties that the majority of people use to think about other people". It is the author's belief that this statement can be further expanded into the view that technical students can employ the same strategies they use in to solve problems and reason in Mathematics to analyse and solve technical problems with an increased level of technical accuracy.

Transferring Basic Mathematical Knowledge into the Development of Technical English Literacy

The conceptual similarities between Mathematics and literacy can be analysed in five main categories: **structures of the disciplines, thinking processes, comprehension efforts, problem solving properties, and strategic behaviors,** as discussed by Hemphill (2010, p. 7). The following sections will enlarge upon each and corroborate them with examples of carefully selected classroom activities in which technical students transition from basic geometry to enhanced technical literacy.

1. Structure of the disciplines

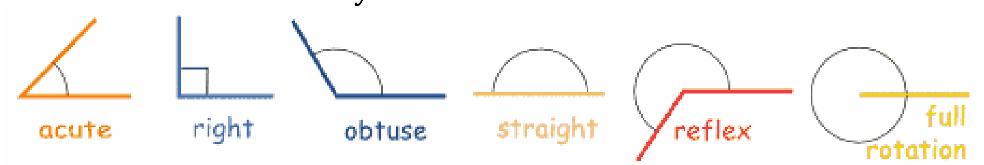
Similar to learning rules and patterns in learning a language with structures of words, sentences, and entire texts, students are able to discover patterns and connections between mathematical facts and operations. Thus, both reading and Mathematics involve hierarchical development of skills and concepts as they progress through increasing levels of understanding (Russell & Dunlap, 1977). This transfer of observed patterns with an increasing degree of difficulty can be harnessed in tackling technical English tasks that require comprehension and accurate output production in the form of providing opinions, solutions and making deductions based on technical input. The concept is illustrated below in a progression of classroom activities that develop technical students' structure-development processes on their path to becoming technical literate, i.e. being able to comprehend and produce output in contextualized professional activities.

Stage 1: Matching Types of Angles – Basic Mathematics

Task description: Match the name with the description for various types of angles. Use the illustration for help, if necessary:

Type of Angle	Description
Acute Angle	an angle that is 180° exactly
Full rotation	an angle that is less than 90°
Right Angle	An angle that is more than a reflex angle
Obtuse Angle	an angle that is greater than 180°
Straight Angle	an angle that is 90° exactly
Reflex Angle	an angle that is greater than 90° but less than 180°

Task Feedback: Check your answers:

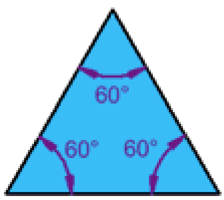
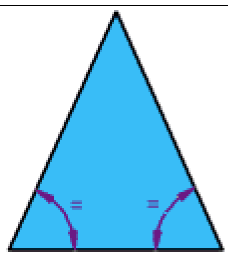
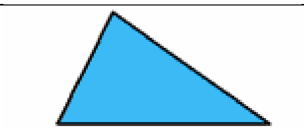


Stage 2 Task Extension: Literacy: Give an example of an object containing each angle type.

Task formulation: Read the following information about Triangles and fill in the blanks:

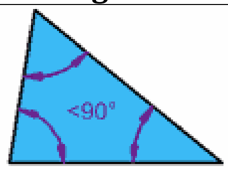
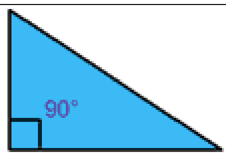
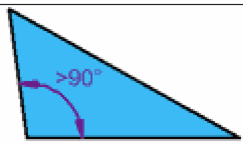
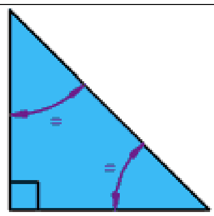
A triangle has …. sides and three angles and the three angles always add to …….°

Equilateral, Isosceles and Scalene are three special names given to triangles that tell how many sides (or angles) are equal.

	Equilateral Triangle Three ……. sides. Three…….. angles
	Isosceles Triangle Two …….sides Two ……. angles
	Scalene Triangle …… equal sides …… equal angles

Stage 3 Extension 2: Literacy – making associations between angle types and triangle types. Visuals are used to render triangle type. Students provide the name of the triangle and a detailed description that differentiates between the triangle types.

Task formulation: Triangles can also have names that tell you what **type of angles** are inside the triangle*:*

<table>
<tr><td>
</td><td>……… Triangle
Describe: ………………………………………
………………………………………………</td></tr>
<tr><td>
</td><td>………Triangle
Describe: ………………………………………..
………………………………………………...</td></tr>
<tr><td>
</td><td>…………... Triangle
Describe: …………………………………………
…………………………………………………</td></tr>
<tr><td>
</td><td>Right-……… Triangle
Describe:……………………………..
………………………………………..</td></tr>
</table>

Stage 4 Extension 3: Literacy: Question comprehension, providing answers.

Task formulation: Answer the following questions using what you have learned about triangles their angles and side lengths.

1. If a triangle is a right triangle, then how many angles are acute?
2. How many angles in a right triangle are right angles?
3. How many degrees are there in a right triangle?
4. What is an obtuse angle?
5. How many obtuse angles are in an obtuse triangle?
6. If there is one obtuse angle, how many angles are acute?
7. If a triangle is equiangular, what is the measure of all three angles?
8. What does the word „interior angle” mean?
9. True or false. The side lengths of a scalene triangle are all equal.
10. True or false. The side lengths of a scalene triangle are all different.

11. True or false. The side lengths of an equilateral triangle are all equal.

12. True or false. An isosceles triangle has two side lengths the same and one different.

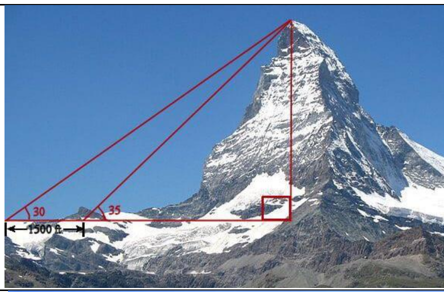
13. True or false. A scalene triangle can also be an isosceles triangle.

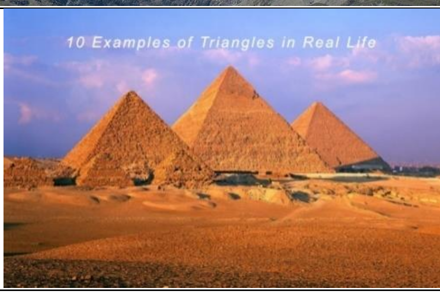
14. True or false. An equilateral triangle is also equiangular.

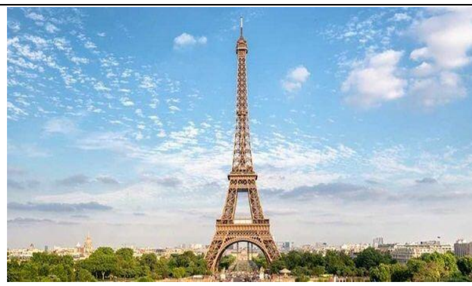
15. True or false. A scalene triangle can not be an acute triangle.

Stage 5 Extension 4: **Technical Literacy**: Making technical inferences based on visuals

Task formulation: Analyse the types of triangles that can be associated with the pictures. Does the triangle type impact the performance of the object from a technical point of view? Explain.





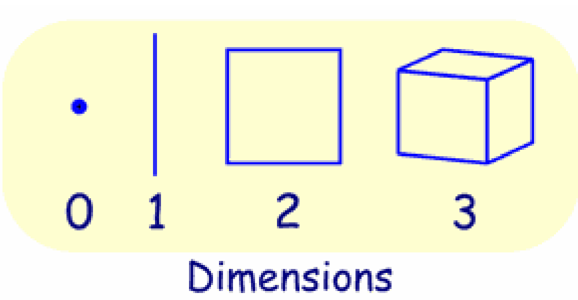
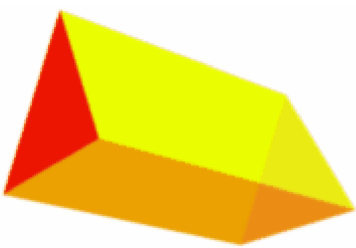


2. Thinking processes refer primarily to people's ability to think symbolically as they „let symbols represent experiences and ideas" (Goodman, 1996, p. 12). Consequently they created language and Mathematics languages as systems of symbols, codes and channels in which letters, words, sentences on the one hand and equations, numbers, formulae, on the other, represent spoken sounds, notions, quantities, shapes, and other real life and virtual phenomena. Understanding the connection between written Mathematics and language and the actual meaning of the symbols enables people to perceive the real-life purpose of Mathematics, which is to code in the language of science the realities around us. Therefore, technical students must use abstract thinking to make sense of the code and possess motivation to learn about the world in a tight-knit web of Mathematics and language. Additionally, a strong similarity can be noticed between literacy and Mathematics as regards metacognition (Dale & Cuevas, 1987; Fogelberg et al., 2008; Hartman, 2001; Minton, 2007). As with reading, people resolving mathematical tasks ask questions about the meaning of the problem, make predictions about appropriate actions to adopt and solutions to find, check the accuracy of their chosen problem, use a solving strategy, and go back to identify and alter any mistakes (Minton, 2007). Thus, students will resort to the same behaviors as they contemplate and monitor their thinking during the reading and Mathematics problem solving processes. The following section will practically describe a set of activities that can be used to gradually transition basic knowledge of Mathematics into technical literacy during technical language classes.

Stage 1 Basic Mathematics: input based on visuals

Task formulation: Read the information below and fill in the blanks with meaningful words:

Geometry represents the ……. of <u>shapes</u> and their properties.

	**Point, Line, Plane and Solid** A Point has no dimensions, only position A Line is ….-dimensional A Plane is …..-dimensional (2D) A Solid is …….-dimensional (3D)
	Plane Geometry is about flat …….. like lines, circles and triangles, shapes that can be …… on a piece of paper.
	Solid Geometry is about …..dimensional objects like cubes, prisms and pyramids.

Stage 2 Task 2: Inference based on previous input – basic mathematics using symbolism

Task Formulation:

- Name 5 objects which contain plane geometry shapes.
- Name 5 objects which contain solid geometry shapes.
- Draw a house with plane geometry shapes, then with solid geometry shapes.

Variation: Think about the objects we use in everyday life and about the activities we perform. Give three examples of objects containing geometrical shapes and three examples of activities in which basic knowledge of geometry is necessary.

Stage 3 Extension: Technical Literacy – turning word symbolism into mathematical shape. Using relevant words to differentiate between geometrical shapes.

Task formulation: draw a technical object (tool, pare part, mechanical system etc.) that contains each of the mentioned solid shapes.

sphere		pyramid	
cylinder		rectangular prism (cuboid)	
cube		triangular prism	
cone			

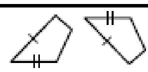
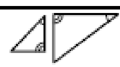
Stage 4 Basic mathematics visual input: using symbols instead of words.

Task formulation: Study the list below with Common Symbols used in Mathematics, which are often preferred because they save time and space when writing:

Symbol	**Meaning**	**Example**	**In Words**
Δ	Triangle	ΔABC has 3 equal sides	*Triangle ABC has three equal sides*
$\angle$	Angle	$\angle$ABC is 45°	*The angle formed by ABC is 45 degrees.*
$\perp$	Perpendicular	AB $\perp$ CD	*The line AB is perpendicular to line CD*

$\parallel$	Parallel	EF $\parallel$ GH	*The line EF is parallel to line GH*
o	Degrees	360° makes a full circle	
∟	Right Angle (90°)	∟is 90°	*A right angle is 90 degrees*
$\overline{AB}$	Line Segment „AB”	AB	*The line between A and B*
$\overleftrightarrow{AB}$	Line „AB”	$\overleftrightarrow{AB}$	*The infinite line that includes A and B*
$\overrightarrow{AB}$	Ray „AB”	$\overrightarrow{AB}$	*The line that starts at A, goes through B and continues on*
$\cong$	Congruent (same shape and size)	ΔABC ≅ Δ DEF	*Triangle ABC is congruent to triangle DEF*
~	Similar (same shape, different size)	ΔDEF ~ Δ MNO	*Triangle DEF is similar to triangle MNO*
∴	Therefore	*a=b* ∴ *b=a*	*a equals b, therefore b equals a*

Geometric Symbols

Example	Meaning	Example	Meaning
$\angle A$	angle *A*	$\overrightarrow{AB}$	vector *AB*
$m\angle A$	measure of angle *A*	⌐	right angle
$\overline{AB}$	line segment *AB*	$\overleftrightarrow{AB} \parallel \overleftrightarrow{CD}$	Line *AB* is parallel to line *CD*.
AB	measure of line segment *AB*	$\overleftrightarrow{AB} \perp \overleftrightarrow{CD}$	Line *AB* is perpendicular to line *CD*.
$\overleftrightarrow{AB}$	line *AB*	$\angle A \cong \angle B$	Angle *A* is congruent to angle *B*.
$\triangle ABC$	triangle *ABC*	$\triangle A \sim \triangle B$	Triangle *A* is similar to triangle *B*.
▭ *ABCD*	rectangle *ABCD*		Similarly marked segments are congruent.
▱ *ABCD*	parallelogram *ABCD*		Similarly marked angles are congruent.

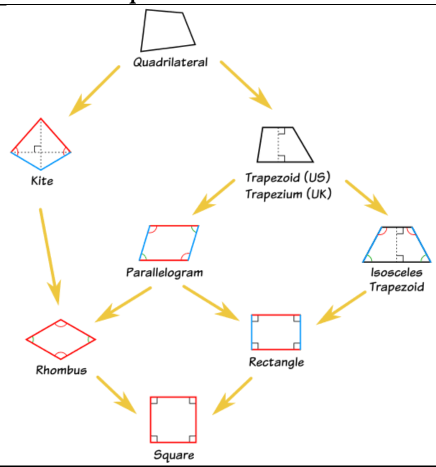
Example: When someone writes: In ΔABC, $\angle$BAC is ∟, they are really saying: „In triangle ABC, the angle BAC is a right angle”

Stage 5 Extension: Write a mathematical problem/demonstration using some of these symbols and present it to your colleagues to check if it is correctly formulated.

Variation: Write a paragraph about an object or tool used in engineering which has geometrical shapes in it, use symbols to bypass word descriptions. Include relevant clues to help colleagues guess the tool.

Stage 6: Technical literacy: identifying relevant critical details

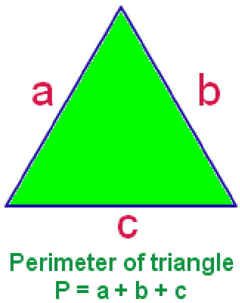
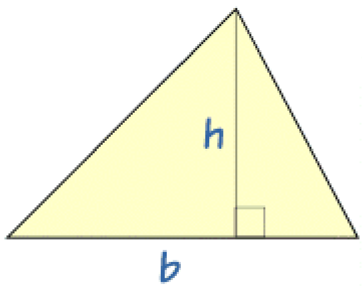
Extension: Read the following text and the simplified chart below rendering the relation between the various types of quadrilaterals and answer the questions:

<table>
<tr>
<td>
</td>
<td>- The only regular quadrilateral is a square. So all other quadrilaterals are irregular.
- Quadrilateral definitions are inclusive. For example: a square is also a rectangle.
So we include a square in the definition of a rectangle. This may seem odd because in daily life we think of a square as not being a rectangle but in mathematics it is.</td>
</tr>
<tr>
<td colspan="2">- Is a Square a type of Rectangle?
- Is a Rectangle a type of Kite?
- Is a trapezoid parallelogram?
- Is a rectangle a trapezoid?
- Is a rhombus a rectangle?
- Is a kite an isosceles trapezoid?
- Is a rhombus a parallelogram?</td>
</tr>
</table>

3. Comprehension efforts According to Brown (1998, p. 191) readers engage in „cognitive processing of letters and words, word meaning, syntax, sentence-level meaning assignment, and linking of sentences at the paragraph level”. As readers and mathematicians alike rely on existing knowledge to construct meaning from texts and numbers, Minton (2007) points out that the two fields correspond in their deep structure schematic systems. Technical students possess the ability to grasp meaning from visual input and achieve comprehension of incomplete syntactic structures. This ability will be useful in professional life when technical students discuss product charts and specs, technical blueprints in the form of diagrams and drawings. Based on their comprehension of the data they will be able to make alterations, diagnose problems and forward solutions. As concerns comprehension efforts, we shall see how students' scope of comprehension can be made to transition from basic Mathematics to technical literacy in the section below.

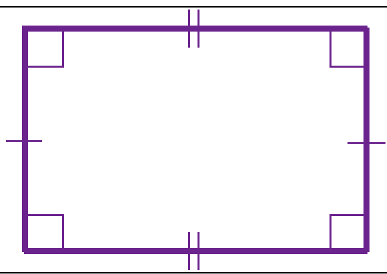
Stage 1 Basic Mathematics: comprehension based on visual input

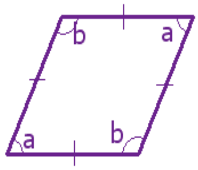
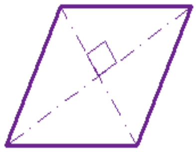
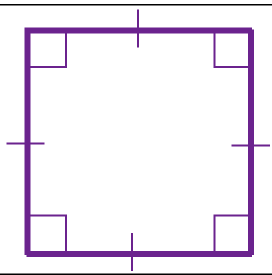
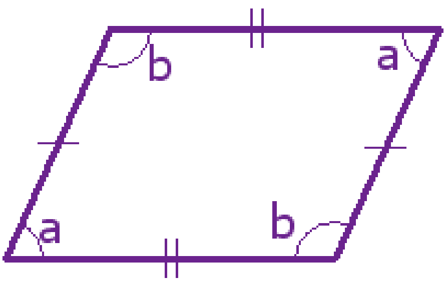
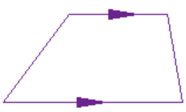
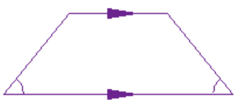
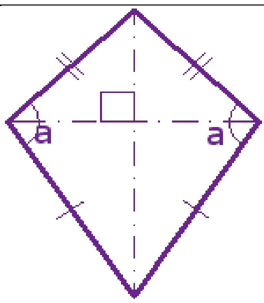
Task formulation: Study the figures below and fill in the gaps in a way that makes sense:

	**The Perimeter** The perimeter can be defined as the .... around the edge of the triangle: we just ..... up the three sides.
	**The area** is ...... of the base times (=multiplied by) height. The formula works for all triangles. Another way of writing the formula is **bh/2** • "b" is the distance along the .... • "h" is the height (measured at ...... angles to the base) • Area = ½ × b × h

Stage 2: Literacy based on visual input: intermediate level of comprehension

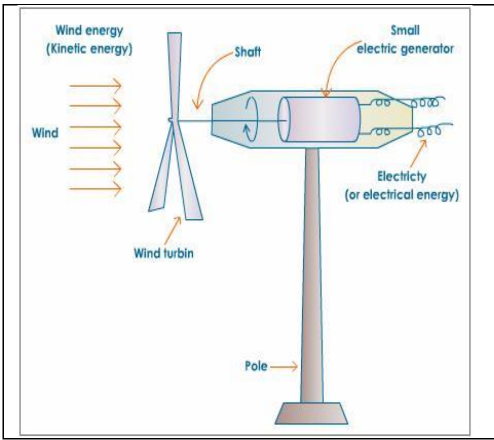
Task formulation: Read about the following geometrical shapes and fill in the blanks:

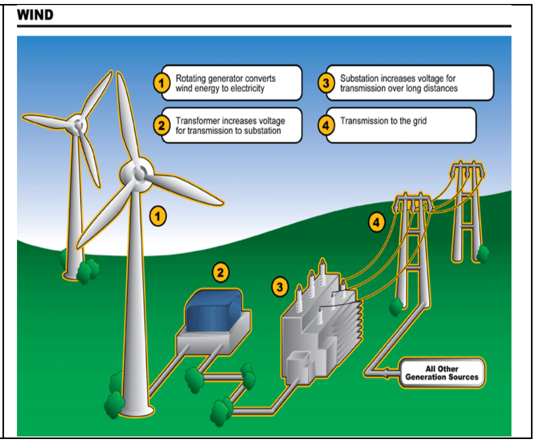
	☐ *means „right angle"* | and || *show equal .... sides*

 	The Rhombus: A rhombus is a ......-sided shape where ..... sides have equal ..... Also opposite sides are parallel *and* opposite angles are equal. Also, the diagonals (the dashed lines in second figure) of a rhombus bisect each other at .... angles.
	The Square: A square has ...... sides and every angle is a right angle (90°), opposite sides are .... A square also fits the definition of a rectangle (all angles are 90°), and a rhombus (all sides are equal length).
	The Parallelogram: A parallelogram's opposite sides are .... and equal in length. Also ...... angles are equal (angles „a” are the same, and angles „b” are the same) NOTE: Squares, Rectangles and Rhombuses are all Parallelograms!
  Trapezoid Isosceles Trapezoid	The Trapezoid (UK: Trapezium) A trapezoid (called a trapezium in the UK) has a pair of opposite ....sides. It is called an Isosceles trapezoid if the sides that aren't parallel are ...... in length and both ...... coming from a parallel side are ....
	The Kite: It has two ...... of sides. Each pair is made up of adjacent sides that are .....in length. The angles are equal where the pairs meet. Diagonals (dashed lines) meet at a ..... angle, and one of the diagonals ...... (=cuts equally in half) the other.

Stage 3: Technical literacy – corroborating shapes with functioning principles.

Task formulation: study the pictures below. Identify as many geometrical shapes in the pictures of the wind turbines system. Explain how the shape aids the functionality of the part in which it occurs.

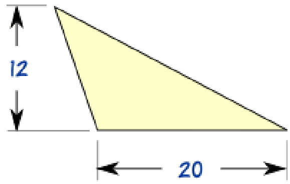




4. Problem solving While reading, people employ „operations or strategic activities…to problem-solve the puzzle of getting the messages from a text, or putting messages into texts" (Clay, 2005, p. 34). Readers employ more decoding or comprehension strategies, such as breaking input into chunks or reading multiple times to find solutions to the problems they encounter at the letter, word, or overall meaning levels (Olshavsky, 1976-1977). This mental process of recognizing a problem, predicting an answer, and using problem solving strategies to develop an accurate solution mimics the problem solving that occurs among mathematicians. Additionally, technical students display the ability to formulate problems based on comprehended input, which renders a higher order degree of technical literacy. Such formulated problems often represent the condensed form of a technical situation broken down into numbers and symbols that technical thinking can resolve. The same problem formulated in words is often perceived as cryptic and takes longer to resolve, as demonstrated below.

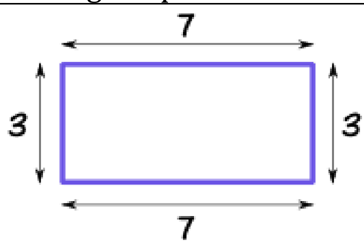
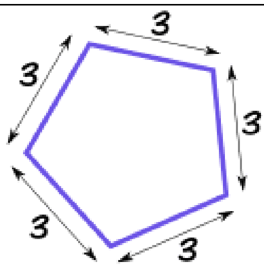
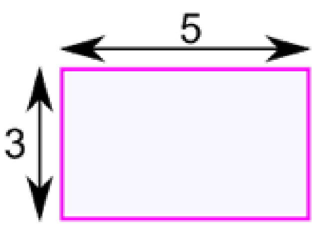
Stage 1 – Basic Mathematics – solving a problem with the help of formulae

Task formulation: read the problem formulated in words (A) and with visual aids (B)

<table>
<tr><td>A) problem in words
Calculate the area of a scalene triangle with the obtuse angle height of 12cm and the adjoining side of 20 cm.</td><td>B) With visual and symbolic input

Area=? cm2</td></tr>
<tr><td colspan="2">(Note: 12 is the height, not the length of the left-hand side)
Formula: Area = ½ × b × h
½ × …. × …. = ……
The base can be any side, but make sure the „height” is measured at right angles to the „base”.</td></tr>
</table>

Stage 2: basic Mathematics – eliciting rules and formulae

Task formulation: Fill in the blanks to obtain true statements in calculating the perimeter and area:

<table>
<tr><td></td><td>Perimeter is the …….. around a two-dimensional shape.
Example 1: the perimeter of this ……… is 7+3+7+3 = 20
Explain how one calculates the perimeter of a rectangle</td></tr>
<tr><td></td><td>Example 2: the perimeter of this regular …….. is 3+3+3+3+3 = 5×3 = 15
Explain how one calculates the perimeter of an equal-sided shape.</td></tr>
<tr><td></td><td>Area = w × h
w = width
h = height. The width is 5, and the height is 3, so we know w = 5 and h = 3. So: Area = 5 × 3 = 15
Explain how one calculates the area of a rectangle.</td></tr>
</table>

Stage 3 – Technical literacy-creating a problem

Task formulation: Draw a triangle, specify the height in the form of an equation and the base and ask your classmate to calculate the area.

Stage 4 Technical literacy – describing calculus and building challenges.

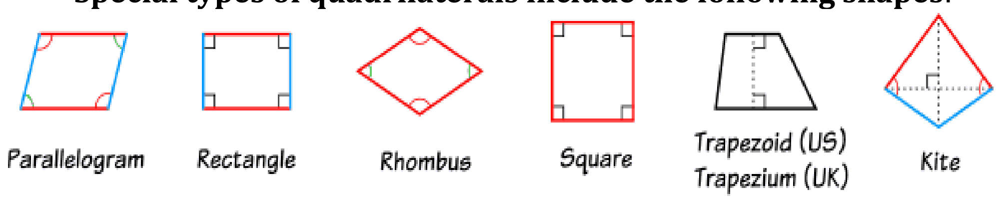
Task formulation Describe the technical challenges of building a 20 metres pyramid from limestone. What calculations might be necessary?

5. Strategic behaviours Fogelberg et al. (2008) and Hyde (2006) postulate that literacy as well as Mathematics rely heavily on making connections and predictions, asking questions, self-regulating, inferring, visualizing, summarizing, and determining importance. Adding to this list, Minton (2007) discusses how people improve their numeracy and literacy comprehension by expanding their vocabulary and synthesizing ideas. Using decomposition strategies or solving a simpler problem before tackling the more difficult one are strategic behaviours used in both domains. Technical students regulate and enlarge upon strategic behaviours to advance understanding and task completion from simple to complex or by breaking down task into more manageable tasks. Also they resort to making predictions, inference and deduction when they make mathematical demonstrations, when thy use hypotheses to draw geometric shapes and demonstrate that resulting figures inscribed in the respective shapes belong to a particular shape type, when they draw technical parts with CAD tools and must determine relationships between various facets of the designed parts etc. Their technical literacy will largely depend on their ability to expand and transfer strategic behaviours learnt during Mathematics classes to the newly generated domain of technics in which they need to operate.

Stage 1 Basic Mathematics – observation and deduction:

Task formulation: Fill in the blanks with details that make the statements true:

Special types of quadrilaterals include the following shapes:



The Rectangle: A rectangle is a ……-sided shape where every angle is a …… angle (90°). Also opposite sides are ………. and of equal length.

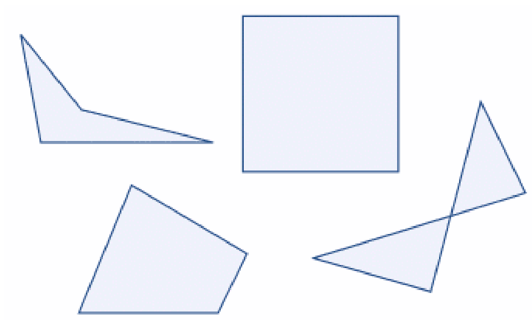
Stage 2: Strategic behaviour – replicate a definition using critical details

Task formulation: create your own definitions of the remaining special quadrilaterals using the example above. Include any relevant details that differentiate between the special quadrilaterals.

Stage 3: Strategic behavior: eliciting definitions

Task formulation: study the shapes below. Fill in the gaps to obtain true statements about irregular quadrilaterals.

Irregular Quadrilaterals

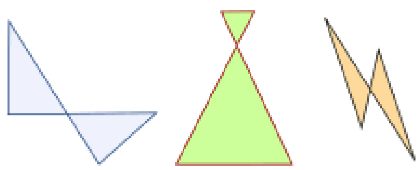


Quadrilateral just means „..... sides" (*quad* means ...., *lateral* means ....). Any ......-sided shape is a Quadrilateral. The .....have to be straight, and it is a ....-dimensional geometrical shape.

Properties

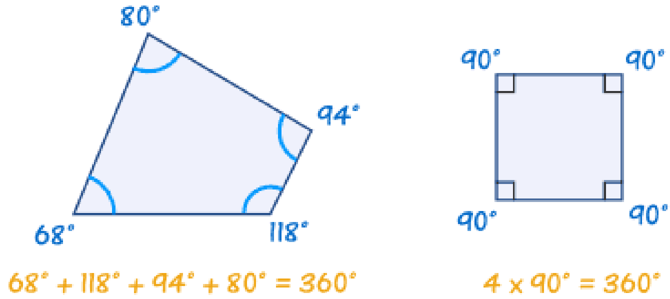
- ...... sides (or edges)
- ....vertices (or corners).
- The interior .... add up to 360 degrees.

Complex quadrilaterals are defined as the quadrilaterals which have .... sides crossing over, thus resulting irregular ....:

	A quadrilateral can sometimes be called: • a **Quadrangle** ("*four ......*"), so it sounds like „triangle" • a **Tetragon** ("*.....* + *gon*"), so it sounds like „pentagon", „hexagon" etc. • a **Polygon**.....(if poly= multi)............

Stage 4 **strategic behavior – rule elicitation (based on deduction)**

Task formulation: Study the images below**.** Write a mathematical rule that applies to all quadrilaterals based on what you notice in the pictures**.**



Stage 5: Technical Literacy: generating output based on given input

Task formulation: Try to draw a quadrilateral, and measure the angles. They should add to **360°.**

Variation – strategic behavior: visualization and summarizing relevant features using shapes and angles.

Task formulation: study the following plug types. Describe their shape using the geometrical shapes you know and pin orientation angles using the angle types you have studied.

Conclusion

Though it might seem particularly challenging to ESP teachers to use basic mathematical knowledge to enhance technical literacy, this approach yields obvious benefits. First and foremost, students learn to use the same thinking processes and strategic behaviours they used in learning basic Mathematics in the quest for technical literacy. As a matter of fact, technical English study is nothing more than science turned practical for engineering purposes. Consequently, basic knowledge of science can be transferred into technical literacy with the appropriate tools for comprehension and learning. The approach of transferring scientific skills in general and mathematical skills in particular to technical English learning provides a boost in production confidence as it relies on strategies that are already familiar (reasoning, summarizing, using symbols, making inference and deduction, carrying out a demonstration based on given hypotheses etc.). Secondly, it provides manageable sequencing of learning and improves learning outcome. Finally, this approach can teach students to self-regulate their learning and can increase awareness of learning strategies which they can later replicate to become autonomous learners.

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